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APPENDIX PREPARED FOR

WATER USE ASSESSMENT

COACHELLA VALLEY WATER DISTRICT

AND

IMPERIAL IRRIGATION DISTRICT

PHASE I REPORT

from the

TECHNICAL WORK GROUP

Stephen M. Jones

Charles M. Burt

Albert J. Clemmens

Marvin E. Jensen

Joseph M. Lord, Jr.

Kenneth H. Solomon

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DRAFT

April 11, 1994

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TABLE OF CONTENTS FOR APPENDIX

TABLE OF CONTENTS FOR APPENDIX (continued)

APPENDIX 1

Statistics and Confidence Intervals
prepared for the TWG by
A.J. Clemmens

Every measurement of a continuous variable, such as water quantity, contains uncertainty regardless of the variable and the method of measurement. All of the methods for estimating beneficial uses require measurement of various quantities and in most cases calculations to determine beneficial use and efficiency. The standard procedure is to determine how accurately we currently know what the beneficial uses are, and what additional measurements are needed to improve estimates for these quantities. First, we must be able to estimate the accuracy of any numerical value resulting from a measurement; then we must be able to determine the influence of the combination of errors on the final estimate. Several statistical equations are needed for this determination, based on a combination of variances.

Statistics. Statistics are numerical values which describe a particular variable of interest. The include expected value, standard deviation, variance, coefficient of variation, confidence intervals, and covariances between variables. Usually, these statistics for a population are not know exactly, but estimated from samples or measurements taken regarding the population. For example, the expected value for the mean of a population, E, can be estimated from individual measurements from the population.

The standard deviation, S, is a standard statistical measure of variability. The standard deviation describes the spread of the distribution of values for a particular parameter. The variance is the standard deviation squared. The following equation is used to compute the variance, and thus standard deviation, when n samples are taken from a population,

$$S_y^2 = \frac{\sum (y_i - M_y)^2}{n-1} \qquad \textbf{(1)}$$

where y is the variable of interest, S_y^2 is the variance of y, M_y is the mean value of y, and the subscript i refers to individual sample values.

In addition, we also use the confidence interval, CI, to represent the range of possible values of a particular variable. For example, if we don't have an exact measurement of a particular variable, we can estimate the range of possible values from available data. This range is used as the confidence interval, from which a standard deviation can be calculated. (Note for statisticians: we define the confidence interval as $\pm$ 2 S regardless of distribution type. For distributions other than normal this confidence interval may not exactly represent 95% confidence).

The coefficient of variation, C_y, is the standard deviation, S_y, divided by the mean, M_y, or

$$C_y = \frac{M_y}{S_y} \tag{2}$$

Combination of Variance Equations - Addition. When adding several quantities of interest, for example x = y + z, the relevant equations for expected value, variance and coefficient of variation are

$$E_x = E_y + E_z \tag{3}$$

$$S_x^2 = S_y^2 + S_z^2 \tag{4}$$

$$C_x^2 = \frac{M_y^2}{M_x^2} C_y^2 + \frac{M_z^2}{M_x^2} C_z^2 \tag{5}$$

Combination of Variance Equations - Multiplication. For multiplication and division, we can also combine the influences of measurement errors. If x = y z, and if y and y z are random variables, then x is a random variable with the expected value determined from

$$E_x = M_y M_z + S_{yz}^2 \tag{6}$$

where S_{yz}^2 is the covariance of y and z. The covariance between two variable is a measure of how well they are correlated.

$$S_{xy}^2 = \frac{\sum (y_i - M_y)(z_i - M_z)}{n-1} \tag{7}$$

If y and z are independent (uncorrelated), then the covariance is zero.

The variance of the product, x = y z can be found from

$$S_x^2 = M_z^2 S_y^2 + M_y^2 S_z^2 + S_y^2 S_z^2 + 2M_y M_z S_{yz}^2 \qquad (8)$$

where higher order terms have been ignored. If y and z are independent, then the coefficient of variation for x is

$$C_x^2 = C_y^2 + C_z^2 + C_y^2 C_z^2 \qquad (9)$$

Combination of Variance Equations - Division. The expected value and variance of a quotient of two random variables, such as x = y/z, can not be computed exactly, even if the correlation between y and z is known. Approximate equations are

$$E_x \approx \frac{M_y}{M_z}\left(1 + \frac{S_z^2}{M_z^2} - \frac{S_{yz}^2}{M_y M_z}\right) \qquad (10)$$

$$S_x^2 \approx \frac{M_y^2}{M_z^2}\left(\frac{S_y^2}{M_y^2} + \frac{S_z^2}{M_z^2} - \frac{2S_{yz}^2}{M_y M_z}\right) \qquad (11)$$

If y and z are independent, then the coefficient of variation for x can be found from

$$C_x^2 \approx C_y^2 + C_z^2 \qquad (12)$$

Assigning Confidence Intervals. The TWG made estimates of the standard deviation or confidence interval for each all values used in water use calculations. These include water sources and destinations, acreage, ET_o, Kc, LR, and any other variables. In most cases, the TWG was conservative in their estimates for the confidence interval. In many cases, a more careful review of the sources of error will improve our confidence in the estimated values. In addition, the equations used to estimate statistics were also chosen to be conservative.

The uncertainty of estimates in this report are given as confidence intervals, ± 2S, expressed as a percent of value. Thus they are in the form of ± 2C. To calculate the confidence interval for a sum product or quotient, the confidence interval must first be expressed in terms of a coefficient of variation. Then one of equations 5, 9 or 12 is used to determine the combined coefficient of variation from which a combined confidence interval results.

It is recognized that several variables of interest have physical limitation, such as efficiencies can't be above 100% and many water uses can't be less than zero. The equations used ignore these restriction. The TWG was careful to point out where these limitation influence the results.

Uncertainty of Water Uses. Calculation of closure terms in any of the water balances included in this assessment are straight forward, as are calculation of the associated confidence intervals. The water balance calculations are primarily addition and subtraction. Equation 5 was used to determine coefficients of variation and confidence intervals. It can be seen from equation 5 that the C's are weighted according to the mean value squared. Thus variables which are of small magnitude have little influence on the combined confidence interval.

Weather-based estimates of ET_c require multiplication ET_o, crop coefficients and acreage. Since ET_o is included in the estimate for each crop, it is not considered as a random error when combining the ET of all crops. Ignoring the higher order term in equation 9, C for ET_c is computed from

$$C_{ETc}^2 = C_{ETo}^2 + C_{Kc}^2 + C_{acre}^2 \qquad (13)$$

where C_{Kc} is the combined C for all crops. A similar situation occurs for calculating beneficial deep percolation for salt removal. We can show that approximately

$$C_{BenDP}^2 \approx C_{ETc}^2 + C_{LR}^2 + C_{ECiw}^2 \qquad (14)$$

In both these cases, the terms on the right-hand-side are independent.

In developing combined estimates for beneficial uses, in some cases all three terms (ET_{iw}, leaching, other uses) are based on ET_{iw}. Since the terms are not independent, equation 5 cannot be applied directly. The resulting equation for beneficia uses becomes

$$B.U. = ET_{iw}(1 + \frac{LR}{1-LR} + 2\%) \qquad (15)$$

The term in parentheses can be treated with equation 5. Then C_{BU} can be computed with equation 9 from C_{ETiw} and $C_{()}$ (for the term in parentheses).

Uncertainty of Performance Measures. The statistics of ratios is always problematic. As seen from equation 10, even if the terms are completely independent, the expected value does not equal the calculated mean value (M_y/M_z). In this report, we did not include expected (mean or average) values because of this complexity. Equation 10 also demonstrates the need to accurately know the amount of water supplied (as reflected in S_z^2) to even determine the expected value for the ratio (efficiency).

In addition, water uses and water supplies are likely not independent. As seem from equation 11, if the covariance is positive, the confidence interval will actually be reduced. That is, if supply and use are positively correlated, ignoring this correlation will provide a conservative (wider) estimate of C and CI.

If the water balance procedures are used to determine ET_{iw}. Then the numerator and denominator in the irrigation efficiency calculations are not only not independent, but both are derived from the same numbers. For example

$$IE = \frac{ET_{iw} + otherBU}{W_{net}} = \frac{W_{net} - nonCU - CU_{nonBU} + otherBU}{W_{net}} \qquad (16)$$

where W_{net} is the net water supply. (Equation 16 is not meant to represent the exact equation used, just the idea). Now, W_{net} must be factored out before the confidence interval on IE can be determined. A similar situation results if ET_{iw} is used to estimate W_{net}. However, ignoring this dependents results in a wider CI, thus being conservative. In most cases examined, the differences in ignoring this effect were not significant. All CI's reported ignore this effect.

References

Mood, A.M., F.A. Graybill, and D.C. Boes, *Introduction to the Theory of Statistics*, McGraw-Hill, New York, 1974.

APPENDIX 2

WATER BALANCE CALCULATIONS

APPENDIX 2

Water Balance Calculations
prepared for the TWG by
A.J. Clemmens

INTRODUCTION

A water balance applied to a hydrologic unit represents a conservation of mass. It is a basic scientific principle and is the fundamental basis for irrigation efficiency evaluations, wether on the field, farm, district or project scale. It is used in hydraulic and hydrologic models to prevent them from producing unrealistic results.

Several variations of water balance calculations were used by the TWG in determining the current sources and destinations of water. The approach was to use measurements or estimates of as many components as possible to calculate the quantity of interest as the closure term that is difficult to quantify with other methods. It is recognized that each water balance has limitations. The numerical value determined for each water source or destination will likely not be the true value. We can only use what ever means are possible for arriving at a number. But an important aspect of this approach is to assign confidence intervals (CI) as estimates of the accuracy of the numbers. By using combination of variance techniques as discussed in Appendix 1, we can determine the accuracy or confidence in the closure term. Details for the two districts follow.

CVWD DETAILS

During Phase 1 of this assessment, three different water balances were used within CVWD:

- district water balance with ET_{iw} as the closure term,
- district water balance with net groundwater pumping as the closure term,
- district-scale field water balance with deep percolation as the closure term.

This latter water balance was made twice, each based on the results of the two district water balances.

Several choices exist for the boundaries of the district water balance for CVWD because of the complex hydrogeology. Horizontally, all land underlain by the aquitard from Indio to the Salton Sea are included in the water balance, even though they are not within ID#1. Also included are all agricultural land within the lower valley that lie outside the aquitard. Vertically, the boundaries extend from the crop canopy to the bottom of the aquitard, and where the aquitard is not present, to the bottom of the root zone. The TWG felt that there was less uncertainty with these boundaries than other choices. With additional data collected during Phase II, other boundaries may be more appropriate.

The district-scale field water balance includes only agricultural fields within the valley.

Data used in water balance calculations for CVWD

Table A2-1 provides additional data that were used in the various water balance calculations. These are values that varied from year to year. Most other values or data were assumed constant.

Reference ET. The TWG made estimates of ET_o from weather station data. These calculations are given in Appendix 7.

Rainfall. Rainfall estimates were made from weather station data, see Appendix 3.

Water Delivered to Coachella Canal. Several different numbers have been used for the amount of water diverted from the All American Canal to the Coachella Canal. We used the numbers reported by CVWD in their *Water Record of the Coachella Canal*.

Coachella Deliveries to IID farms. We used the numbers reported by CVWD in their *Water Record of the Coachella Canal*.

Non-Ag Deliveries. We used the numbers reported by CVWD in their *Water Record of the Coachella Canal*.

CV storm drain flows & direct pumping. We used the numbers reported by CVWD in their *Drainage Water Discharge to Salton Sea*.

Colorado Water Delivered to Farms. We used the numbers reported by CVWD in their *Water Record of the Coachella Canal*.

Crop consumptive Use. The TWG calculated crop consumptive use from weather data. See Appendix 7.

Estimated sprinkler Acreage. There are several acreages reported for crops within the Coachella Valley. We estimated that all truck and vegetable crops in CVWD were irrigated with sprinklers. These acreages were taken from CVWD Annual Reviews and acreages reported to the Bureau of Reclamation. These may not necessarily correspond with acreage numbers used in other parts of this report.

District Water Balance Inputs for CVWD

Table A2-2 and A2-3 give the calculations for the water balance based on net groundwater pumping as the closure for 1987. Within these tables, values for various water inputs and outputs are given along with confidence intervals. Tables A2-6 and A2-7 give similar information for the water balance with ET as the closure. The source of the inputs to these water balances is described in the following.

Water Delivered to Coachella Canal. Several different numbers have been used for the amount of water diverted from the All American Canal to the Coachella Canal. We used the numbers reported by CVWD in their *Water Record of the Coachella Canal*. The TWG estimates that the accuracy of the Parshall Flume to continuously record volume is ± 4%. While some current metering is done to verify calibration, sediment upstream from the flume causes some shift in calibration. Hydraulically, Parshall Flumes are not very good devices. The TWG did not examine the details of these measurements to estimate these confidence levels, but simply chose a conservative estimate.

Coachella canal losses (from All American canal to screens). Bookman-Edmonston '89 Report (Salton-sea flood damage allocation) report estimates from USBR of 9,000 ac-ft/yr over the newly lined section (mp. 48.4) and say losses over remaining unlined section (to mp. 88.7 or screens) is "on the order of" 20,000 ac-ft/yr, for a total losses of 29,000 ac-ft, without identifying a source.

CVWD records (item #40 in CVWD files to TWG), for years 1981 to 1990, after lining of first section of Coachella canal provide measured volumes from a Parshall flume at the head, from a Parshall flume at mp. 48.4, and from current meter measurements (with rated section?) at approximately mp.88.7. Taking the average differences over the 10 years with subtractions for withdrawals (approx. 3,000 ac-ft for each section), we get

mp.0 to 48.4	0	± 8,000 ac-ft
mp.48.4 to 88.7	40,000	± 9,000 ac-ft
mp.0 to 88.7	40,000	± 9,000 ac-ft

The estimate of no loss during the first reach is unreasonable since evaporation alone would be around 4,000 ac-ft. Thus we chose to express only the total loss over the two sections. The value 40,000 appears to be high since it would indicate that the district delivers more water than it receives. The average of the two estimates is approximately 34,000 and we estimated a confidence interval of ± 5,000, or about ± 15%.

Coachella deliveries to IID farms. A small volume of water is delivered to IID farms near the Coachella canal. This area is excluded from the CVWD/IID water use assessment. Values are taken from CVWD records. The accuracy is estimated at ± 5%.

Non-Ag. Deliveries. Water volumes for deliveries to non-agricultural users were taken from CVWD records. This volume is very small and the accuracy is estimated at ± 5%.

Colorado Water Delivered to District. In all cases, this is calculated from other inputs above. The CI is calculated with the procedures given in Appendix 1.

Canal & Reservoir Evaporation The Coachella canal from the screens to Lake Cahuilla is approximately 34.7 mi., with an average width of about 30 ft (rough guess), giving an area of about 126 ac. Lake Cahuilla has an area of about 155 ac. The reference ET for 1987 was 73.5 inches, giving total evaporation as (126 +155)*73.2/12= 1715 ac-ft. This number isn't highly accurate since several of these parameters are rough estimates. We gave this a confidence interval of ± 20%.

CV storm drain flows & direct pumping. We used the numbers reported by CVWD in their *Drainage Water Discharge to Salton Sea*. The TWG felt that the measuring sites for these volumes were not well maintained and likely were not very accurate. We assigned a CI of ± 25%.

Rainfall on irrigated land. Rainfall estimates were made from weather station data, see Appendix 3. Irrigated acreages were taken from acreage assessments made by J.M. Lord Inc. CVWD reported acreages were adjusted in proportion to the J.M. Lord numbers for years where these assessments were not made. The CI is estimated at ± 20%.

Rainfall Evaporation on irrigated land. The portion of rainfall evaporating and not contributing to crop ET were estimated by the TWG in Appendix 3. This proportion was applied to the rainfall calculated above. The CI is estimated at ± 20%.

Rainfall runoff on fallow land. Only that portion of rainfall that ran off from fallow land was included in the water balance. (See Phreatophyte ET). This was based on an estimate of 15,000 acres of phreatophytes and 14% runoff. These estimates are all rough. A CI of ± 20% was assigned.

Returnflow from non-agricultural discharges. The Valley Sanitary District, which includes the cities of Indio and Coachella, discharges approximately 4.6 MGD, or about 5153 ac-ft. Some of this is applied to cropped acreage, but it is unclear whether this acreage is included in estimates of agricultural acreage. We estimate another 200 ac-ft from other sources, for a total of 5353. These is significant uncertainty in this volume so we gave it a CI of ± 50%.

Storm inflow (Whitewater River). CDWR Bulletin 108, pg 133, estimates

Whitewater river flood flows at 3600 ac-ft. However on pg. 140, they estimate them as 0 since they are insignificant. Considering that CVWD only measures flow in the Coachella Valley Storm channel monthly, they would likely not record any flood flows that did pass through. Thus the range of estimates is 0 to 3600 ac-ft, or 1800 ac-ft ± 100%.

Subsurface flow to drains (external sources). CDWR bulletin 108, pg 133, estimated, from the 1961 study, that 2400 ac-ft of subsurface was picked up by drains. At that time there were several natural flowing wells in the area. The decline in groundwater levels would suggest that this amount of flow would be considerably reduced, particularly since natural seeps in outlying areas have mostly dried up. We estimate this flow to range from 0 to 1000 ac-ft, or 500 ac-ft ± 100%.

Subsurface outflow to Salton Sea. With boundaries of the volume balance being taken as including the aquiclude and not the underlying aquifer, previous estimates of flow to the sea are not relevant. The often cited 30,000 ac-ft is misleading. In CDWR bulletin 108, pg 133, they indicated flows of 33,000 ac-ft from 1935-36 and 27,800 ac-ft from 1956-57. With the decline in groundwater levels, current values would be substantially reduced. However, this doesn't apply to this volume balance since the lower aquifers are not included. This represents a difference between the volume balances of CVWD and IID.

Because of drainage water pumping at the edge of the sea, the water levels within the aquitard are below sea level, suggesting a flow from the sea not to the sea. Analysis at IID showed the same gradient away from the sea, but indicated that no flow actually existed. Even if flow existed, it would be small. We give this a rough estimate of 200 ac-ft, ± 100%.

Evaporation from drains, rivers and phreatophytes. Estimates were made of phreatophyte acreage within ID#1 at about 5,000 ac, most with sparse vegetation. The ET of these phreatophytes was estimated to be less than 3 ac-ft/ac on average. This acreage did not include phreatophytes along drains and rivers. We estimated that this was only about 1/3 of the area of Phreatophytes. As a rough guess we estimate phreatophyte ET at 40,000 ac-ft, with a CI of ± 50%.

Other district inflows minus outflows. This is calculated from the other inputs given above. It is included for simplicity in later calculations. The CI is calculated with the procedures in Appendix 1.

Irrigation Water Crop consumptive use, ET_{iw}. In Table A2-2, crop ET of the irrigation water was estimated from weather data as given in Appendix 7. The confidence interval was calculated there based on the components that enter into the calculations. For CVWD, CI on crop ET is ± 12%.

Sprinkler evaporation. We assumed that sprinklers were used on all vegetable and truck crops. We estimated application of 12 inches with 15% evaporation. These losses include evaporation from water droplets, wind drift, and addition non-beneficial evaporation from the wet soil surface. (See sprinkler acreage above). The CI is estimated as ± 20% (which in retrospect looks low).

Farm pond evaporation J.M. Lord inc. conducted a survey and identified 436 ac. of farm reservoirs. Evaporation estimated as ET_0, as discussed in Appendix 5. The CI was estimated as ± 20%.

Other farm evaporative losses. Evaporation losses occur over the area covered by unlined ditches, turn rows, borders, etc. We estimate that these losses amount to about 2% of crop ET, with a CI of ± 100%.

Net district supply. This volume is an intermediate closure term in the water balance. It is the total water supplied less reuse within the district. The CI is computed as described in Appendix 1.

Net groundwater pumping. The net groundwater pumping is the closure term in one of the district water balances. It is the amount of groundwater that is either consumed or that flows to the Salton Sea. It is the total of groundwater pumped minus an deep percolation or seepage which returns to the underlying groundwater.

Effective rainfall. Effective rainfall is the amount of rainfall which goes to satisfy crop ET. This amount must be subtracted from ET_c to determine ET_{iw}, which is the amount of irrigation water beneficially used by the crop as ET. For these calculations, the irrigated acreage was assumed as 62,300 ac for all years. This amount is estimated as 34% of the total rainfall (see Appendix 3), with a CI of ± 20%. **Effective rainfall was inadvertently omitted from the water balance calculations for net groundwater pumping in CVWD.**

Additional Inputs for District-scale Field Water Balance, CVWD

Colorado water delivered to farms. This volume was taken from CVWD records. The CI was conservatively estimated as ± 5%.

Tailwater runoff. Tailwater runoff is not zero, but is insignificant. It is certainly less than 1,000 ac-ft/yr. We estimate 500 ac-ft with maximum uncertainty (± 100%).

Deep percolation return flow. This is the portion of deep percolation water that is picked up in tile drains and flows to the Salton Sea or is consumed by phreatophytes. This is an intermediate closure term in the water balance.

Groundwater recharge of deep percolation water. From observations during the 1960's and before, there appeared to be natural seeps, indicating a general upward movement of water. However, existing groundwater levels within the area of the aquitard appear to be lower than the water levels within the aquitard, indicating the potential for downward movement. In CDWR Bulletin 108, pg 125, it was estimated that 13 to 15% of the irrigated area lied outside the aquitard (based on 66,660 irrigated ac., which is not too different from current acreage). The deep percolation from fields outside the aquitard should recharge the groundwater and not reach the drains. Combining the 13-15% area with the small amount of downward movement within the aquitard, we roughly estimate that 15% of the deep percolation water from irrigated agriculture recharges the groundwater and is not picked up by surface or pumped drains. Since the amount of deep percolation which recharges groundwater depends on the amount of deep percolation return flow calculated above, the confidence interval also is influenced by the CI of that estimate. We estimate that the 15% proportion has a confidence interval of ± 15%. These two CI's are combined as described in Appendix 1 to give a CI for this quantity.

Deep percolation. Deep percolation is computed as the sum of the above two deep percolation quantities. The CI results from those estimates.

Fish and duck pond evaporation. Total groundwater pumping for agricultural purposes in the lower Coachella valley also include water which is evaporated by fish and duck ponds. The report on CVWD efficiencies by Boyle cites this acreage as 988 ac. This acreage is multiplied by ET_o to arrive at a total volume. The CI is estimated at ± 25%.

Pumped Deliveries. There is considerable controversy concerning the amount of water pumped for irrigation within CVWD. This was one of the main criticisms of the Boyle-CVWD report provided in the J.M. Lord Inc. The TWG agrees that this amount is not well known. It is a closure term in one water balance. For the water balance where ET_c was the closure, we estimated the volume to lie between 80,000 and 180,000 ac-ft, or 130,000 ± 50,000 (± 40%). This estimate was made prior to computing the water balance where it was used as a closure term.

Gross farm irrigation deliveries. This is the sum of pumped and Colorado River water deliveries, with the CI computed for this sum.

Summary of CVWD water balances

Tables A2-4 and A2-5 give the water balance results used in subsequent calculations for the years 1987-1992. The water balance with net pumping as the closure (Tables A2-2 and A2-3) gave better estimates than the water balance with ET_{iw} as the closure (Tables A2-6 and A2-7).

Effective rainfall was inadvertently omitted from the water balance calculations for net groundwater pumping in CVWD. Adding this to the water balance would increase estimates of groundwater pumping by about 5,000 ac-ft/yr and would decrease the range of district and average farm IE's by about 1%.

IID Details.

During Phase 1 of this assessment, two different water balances were used within IID:

- district water balance with ET_{iw} as the closure term,
- district-scale field water balance with deep percolation as the closure term.

The boundaries for the district water balance include the irrigated area of the Imperial valley, from the Mexican border on the south to the Salton Sea on the north and from the East Highline canal on the east to the desert on the west. The vertical boundaries include the aquifer under the valley.

The district-scale field water balance includes only agricultural fields within the valley.

Data used in water balance calculations for IID

Table A2-8 provides additional data that were used in the various water balance calculations. These are values that varied from year to year. Most other values or data were assumed constant.

Reference ET. The TWG made estimates of ET_o from weather stations in the valley. These calculations are given in Appendices 4 and 6.

Rainfall. Rainfall estimates were made from weather station data, see Appendices 3 and 6.

Delivery to All American canal at Pilot Knob. These values were taken from IID records.

Water Delivered to Coachella Canal. Several different numbers have been used for the amount of water diverted from the All American Canal to the Coachella Canal. For IID water balances, we used the numbers reported by IID water control, as reported by Boyle.

Deliveries to IID farms above EHL. We used the numbers reported by IID water control, as reported by Boyle.

Non-Ag Deliveries. We used the numbers reported by IID water control, as reported by Boyle.

Alamo River flow to Sea. We used the numbers reported by IID water control, as reported by Boyle.

New River flow to Sea. We used the numbers reported by IID water control, as reported by Boyle.

Direct inflow to Sea. We used the numbers reported by IID water control, as reported by Boyle.

Surface inflow from Mexico. We used the numbers reported by IID water control, as reported by Boyle.

Colorado Water Delivered to Farms. We used the numbers reported by IID water control, as reported by Boyle.

Estimated tailwater. Tailwater estimates were taken from the Boyle report, which reflected acreage of various crops and estimates of tailwater percentage by crop from previous IID studies.

Net irrigated land. We used the numbers reported by Boyle from IID water reports.

Estimated sprinkler Acreage. We estimated that all truck and vegetable crops in IID were irrigated with sprinklers. These acreages were taken from IID Annual Reports as reported by Boyle.

District Water Balance Inputs for IID

Table A2-9 and A2-10 give the calculations for the water balance based on irrigation water crop consumptive use as the closure for 1987. Within these tables, values for various water inputs and outputs are given along with confidence intervals. The source of the inputs to these water balances is described in the following.

Delivery to All American canal at Pilot Knob. These values were taken from IID records. Discussions with IID staff indicate that this is a very good current measurement site. The TWG did not evaluate the data collection program or look at details of the data. For now a conservative estimate of the confidence interval was used, ± 3%. Additional analysis could be used to refine this number if needed.

Water Delivered to Coachella Canal. Several different numbers have been used for the amount of water diverted from the All American Canal to the Coachella Canal.

We used the numbers reported by IID water control as reported by Boyle. The TWG estimates that the accuracy of the Parshall Flume to continuously record volume is ± 4%. While some current metering is done to verify calibration, sediment upstream from the flume causes some shift in calibration. Hydraulically, Parshall Flumes are not very good devices. The TWG did not examine the details of these measurements to estimate these confidence levels, but simply chose a conservative estimate.

Evaporation between Pilot Knob and East Highline Canal (All American Canal). From Boyle report on IID, pg 48, evaporative surface area estimated at 756 Ac. Boyle report used evaporation as $ET_0/0.68$, however ET_0 is a better estimate. Evaporation was adjusted accordingly. ET_o values can be found in Appendices 4 and 6. The CI for evaporation is estimated as ± 10% (although in retrospect this looks low).

Seepage between Pilot Knob and EHL. These values were estimated from USBR studies as reported by Boyle. The TWG used a CI of ± 15% (although in retrospect this looks low).

Deliveries to IID farms above EHL. A small volume of water is delivered to IID farms near Drop 1. This area is excluded from the CVWD/IID water use assessment. Values are taken from IID water control. The accuracy is estimated at ± 5% (although in retrospect this looks low).

Non-Ag. Deliveries. Water volumes for deliveries to non-agricultural users were taken from IID water control. This volume is very small and the accuracy is estimated at ± 5%.

Colorado Water Delivered to District. In all cases, this is calculated from other inputs above. The CI is calculated with the procedures given in Appendix 1.

Canal & Reservoir Evaporation. The estimates of canal and reservoir evaporation were taken from the Boyle report on IID. These were adjusted to reflect the TWG's estimate of ET_o and to remove the adjustment to evaporation relative to ET_o (i.e., $K_{evap}=1.0$ for reservoirs).

Alamo River flow to Sea. We used the numbers reported by IID water control, as reported by Boyle. The TWG visited the measurement site and discussed hardware and procedures, but did not do a thorough evaluation. We assign an estimate for CI of ± 8%.

New River flow to Sea. We used the numbers reported by IID water control, as reported by Boyle. The TWG visited the measurement site and discussed hardware and procedures, but did not do a thorough evaluation. We assign an estimate for

CI of ± 8%.

Direct inflow to Sea. We used the numbers reported by IID water control, as reported by Boyle. The TWG did not visit any of these measurement sites. We assign an estimate for CI of ± 10%.

Surface inflow from Mexico. We used the numbers reported by IID water control, as reported by Boyle. The TWG visited the measurement site and discussed hardware and procedures, but did not do a thorough evaluation. We assign an estimate for CI of ± 10%.

Rainfall on irrigated land. Rainfall estimates were made from data from three CIMIS weather stations, see Appendix 3. Irrigated acreages were taken from the Boyle report on IID. The CI is estimated at ± 20%.

Rainfall Evaporation on irrigated land. The portion of rainfall evaporating and not contributing to crop ET were estimated by the TWG in Appendix 3. This acreage was applied to the rainfall calculated above. The CI is estimated at ± 20%.

Rainfall runoff on fallow land. Only that portion of rainfall that ran off from fallow land was included in the water balance. (See Phreatophyte ET). This was based on an estimate of 15,000 acres of phreatophytes and 14% runoff. These estimates are all rough. A CI of ± 20% was assigned.

Returnflow from non-agricultural discharges. The estimates from the Boyle report on IID were used. These is some uncertainty in this volume so we gave it a CI of ± 30%.

Storm inflow (Mesa). The current water balances for IID used the Boyle report's estimate for 1987. Here it was not adjusted by year. It was assigned a CI of ± 30%, which appears to be much too low. (Although this will have an insignificant effect on final CI's).

Subsurface flow to drains (external sources). In the current water balance, we used the values reported by the Boyle report on IID with a CI of ± 30%. Current estimates of groundwater conditions suggest that less groundwater flow is coming from Mexico than reported in earlier years. In retrospect, this estimate appears high and the confidence interval appears too narrow. Both the value and CI should be adjusted in future water balances.

Subsurface outflow to Salton Sea. The estimate of 2,000 ac-ft reported in numerous reports since 1964 as subsurface flow to the Salton Sea appears to have been an off-the-cuff estimate of the maximum. The TWG therefore suggests that the range is 0 to 2,000, or 1,000 ± 100%. Local groundwater flow near the surface is considered negligible.

Evaporation from drains, rivers and phreatophytes. Boyle IID report, pg B-84, estimated evaporation from phreatophytes, drains and rivers. Phreatophytes evaporation was estimated at $0.9*ET_0$, which appears reasonable. Water surface evaporation was estimated at $ET_0/0.75$, while ET_0 is a more reasonable estimate. The volumes of phreatophyte ET were computed with these adjustments, assuming surface areas from Boyle report and ET_0 from CIMIS estimates (see Appendix 4). The CI was assigned ± 20%, because the acreage was carefully determined.

Other district inflows minus outflows. This is calculated from the other inputs given above. It is included for simplicity in later calculations. The CI is calculated with the procedures in Appendix 1.

Irrigation Water Crop consumptive use. ET_{iw} was estimated two ways: from a combination of weather data and alfalfa yield information as given in Appendix 6 and from a water balance (Table A2-4). For weather based ET, the confidence interval was calculated based on the components that enter into the calculations. For IID, CI on weather based crop ET is ± 7%. For water balance ET estimates, the CI was determined from closure in the water balance with the methods of Appendix 1.

Sprinkler evaporation. We assumed that sprinklers were used on all vegetable and truck crops. We estimated application of 6 inches with 15% evaporation. These losses include evaporation from water droplets, wind drift, and addition non-beneficial evaporation from the wet soil surface. (See sprinkler acreage above). The CI is estimated as ± 25% (which in retrospect looks low).

Farm pond evaporation The TWG estimated 50 ac. of farm reservoirs. Evaporation estimated as ET_0, as discussed in Appendix 5. The CI was estimated as ± 25%.

Other farm evaporative losses. Evaporation losses occur over the area covered by unlined ditches, turn rows, borders, etc. We estimate that these losses amount to about 2% of crop ET, with a CI of ± 100%.

Net district supply. Is an intermediate closure term in the water balance. It is the total water supplied less reuse within the district. For IID this is the same as Colorado River Delivered to Farms.

Effective rainfall. Effective rainfall is the amount of rainfall which goes to satisfy crop ET. This amount must be subtracted from ET_c to determine ET_{iw}, which is the amount of irrigation water beneficially used by the crop as ET. This amount is estimated as 34% of the total rainfall (see Appendix 3), with a CI of ± 20%.

Additional Inputs for District-scale Field Water Balance, IID

Colorado water delivered to farms. This volume was taken from IID records. The CI was estimated as ± 5%. In retrospect this CI may be low.

Tailwater runoff. Tailwater estimates were taken from the Boyle report, which reflected acreage of various crops and estimates of tailwater percentage by crop from previous IID studies. The CI was estimated as ± 20%.

Deep percolation. Deep percolation is computed as the remainder in the water balance. The CI results from those calculations.

Summary of IID water balances

Tables A2-11 and A2-12 give the water balance results used in subsequent calculations for the years 1987-1992.

INTERPRETING VARIANCE COMPONENTS

The purpose of calculating normalized variances for each component in a water balance is both to determine the variance, and thus confidence interval, for the remainder, but also to determine which components in the water balance have the most influence on the magnitude of this variance. The normalized variance is expressed here as the normalized coefficient of variation squared, C^2.

For example, consider Table A2-2. The first sum is *Colorado River Delivered to District*. The normalized C^2 is 0.000593, as shown in the far right column. This value is the sum of the normalized C^2 from the terms which are used compute it. The main contributor to this number is the *Water Delivered to Coachella Canal,* which contributes 0.000513, or 0.000513/0.000593 = 86%. Similarly at the bottom of this table, *Net District Supply* contributes 0.047053/0.052988 = 89% of the uncertainty in *Net Groundwater Pumping*. The uncertainty in *Net District Supply* is split mainly between ET_{iw} (0.001334/0.003655 = 36%) and *Other District Inflows and Outflows* (0.002278/0.003655 = 62%).

Similar analyses can be done for the components of other water balances. These analyses were used to guide the TWG in determining priorities in data collection activities in Phase II, with the components causing the most relative amount of uncertianty being given higher priority. However, improving our estimates of water destination was only one aspect considered in the TWG's setting of priorities. Data needs for determining reasonable uses were also considered.

REFERENCES

Banks, H. O.; J. M. Lord, Jr.; B. C. Gabrielsen, Ph.D.; L. D. Reynolds, M.B.A.; G. E. Fogg, Ph.D.; G. T. O'Neill; D. Wichelns, Ph.D.; J. O. Williams. Special Critique of *On-Farm Irrigation Efficiency, Special Technical Report, Coachella Valley Water District*, prepared for CVWD. August 1993.

Bookman-Edmonston Engineering. 1992. Summary Data on Water Operations Affecting Salton Sea. Prepared for United States District Court Case No. 82-1790: Torres Martinez Case.

CVWD Annual Reviews. Annual Review 1990-91, CVWD, (as of 6-30-92) and Annual Review 1989-90, CVWD, (as of 6-30-90).

CVWD Engineer's Report on Water Supply & Replenishment Assessment 1991/1992.

CVWD Water Record of the Coachella Canal 1987-1992.

Coachella Valley Investigation, Bulletin No. 108, The Resources Agency of California, Dept. of Water Resources.

Drainage Water Discharge to Salton Sea, March 1993.

JMLord, Inc. report. Cropped Acreage, ID-#1, for Irrigation Seasons 1968, 1975, 1987, 1992.

JMLord, Inc. survey of farm reservoir acreage.

Styles, S. 1993. On-Farm Irrigation Efficiency: Special Technical Report. Coachella Valley Water District. April. Prepared by Boyle Engineering Corporation.

Styles, S. 1993. On-Farm Irrigation Efficiency: Special Technical Report for Imperial Irrigation District. August. Prepared by Boyle Engineering Corporation.

Table A2-1. Data used for water balance calculation for CVWD.

	1987	1988	1989	1990	1991	1992	Units
Reference ET, ET_o	6.50	6.39	6.32	6.11	5.88	5.93	ft
Rainfall	0.32	0.25	0.06	0.04	0.28	0.53	ft
Water Delivered to Coachella Canal	323	331	323	360	311	299	1,000 ac-ft
Coachella Deliveries to IID farms	3	3	3	3	4	4	1,000 ac-ft
Non-Ag Deliveries	0	0	0	1	0	0	1,000 ac-ft
CV storm drain flows & direct pumping	117	117	111	110	104	101	1,000 ac-ft
Colorado Water Delivered to Farms	282	286	307	315	275	262	1,000 ac-ft
Irr. Water Crop Consum. Use, ET_{iw}	225	222	234	228	212	208	1,000 ac-ft
Estimated sprinkler Acreage	15	16	19	18	17	16	1,000 ac

Table A2-2 District water balance for net pumping in CVWD: detailed calculations for 1987

		Volume (1,000 ac-ft)	Confidence Interval	Normalized c	Normalized c^2
Water Delivered to Coachella Canal		323	±4%	0.0226	0.000513
Coachella Canal losses (up to screens)		(34)*	±15%	0.0085	0.000080
Coachella Deliveries to IID farms		(3)	±5%	0.0003	0.000000
Non-Ag Deliveries		(0)	±5%	0.0000	0.000000
Colorado Water Delivered to District		286	±5%	0.0243	0.000593
Canal and Reservoir Evaporation		(2)	±20%	0.0013	0.000002
CV storm drain flows & direct pumping		(117)	±25%	0.1036	0.010731
Rainfall on Irrig. land		20	±20%	0.0142	0.000197
Rainfall Evap. on Irr. land		(10)	±20%	0.0073	0.000053
Rainfall runoff-fallow land		1	±30%	0.0007	0.000001
Returnflow Non-Ag Discharges		5	±50%	0.0095	0.000090
Storm inflow (Whitewater river)		2	±100%	0.0064	0.000041
Subsurface flow to Drains (external sources)		1	±100%	0.0018	0.000003
Subsurface outflow to Salton Sea		(0)	±100%	0.0007	0.000001
Evap. from Drains, Rivers & Phreat		(40)	±50%	0.0708	0.005014
Other District inflows-outflows		(141)	±25%	0.1277	0.016133
Irr. Water Crop Consum. Use, ET_{iw}		225	±12%	0.0365	0.001334
Effective Precipitation	(oops!)				
Sprinkler Evaporation		2	±20%	0.0016	0.000002
Farm Pond Evaporation		3	±20%	0.0020	0.000004
Other farm evaporative losses		5	±100%	0.0060	0.000036
Other District inflows-outflows		141	±25%	0.0477	0.002278
Net district Supply		376	±12%	0.0605	0.003655
Net district Supply		376	±12%	0.2518	0.047053
Colorado Water Delivered to District		(286)	±5%	0.0770	0.005935
Net groundwater pumping		90	±46%	0.2302	0.052988
Confidence Interval	upper bound	49			
	lower bound	132			
	S	21			

* ( ) indicates negative value

Table A2-3. District-scale field water balance for deep percolation and farm water supply in CVWD: detailed calculations for 1987.

		Volume (1,000 ac-ft)	Confidence Interval	Normalized c	Normalized c'
Colorado Water Delivered to Farms		282	±5%	0.0189	0.000359
Net groundwater pumping		90	±46%	0.0558	0.003109
Net Water Delivered to Ag users		372	±12%	0.0589	0.003468
Net Water Delivered to Ag users		372	±12%	0.1596	0.025479
Irr. Water Crop Consum. Use, ET_w		(225)	±12%	0.0999	0.009976
Sprinkler Evaporation		(2)	±20%	0.0016	0.000003
Farm Pond Evaporation		(3)	±20%	0.0021	0.000004
Other farm evaporative losses		(5)	±100%	0.0164	0.000268
Tailwater Runoff		(1)	±100%	0.0018	0.000003
Deep Percolation return flow		137	±38%	0.1890	0.035734
Deep Percolation return flow		137	±38%	0.1607	0.025818
Goundwater Recharge from Deep Perc		24	±52%	0.0386	0.001493
Deep Percolation		162	±33%	0.1653	0.027311
Confidence Interval	upper bound	108			
	lower bound	215			
	s	27			
Net groundwater pumping		90	±46%	0.1718	0.035734
Fish & Duck pond Evaporation		6	±25%	0.0066	0.000044
Goundwater Recharge from Deep Perc		24	±52%	0.0517	0.00267
Pumped deliveries		121	±39%	0.1961	0.038448
Confidence Interval	upper bound	73			
	lower bound	168			
	s	24			
Colorado Water Delivered to Farms		282	±5%	0.0175	0.000306
Pumped deliveries		121	±39%	0.0588	0.003458
Gross farm irrig. water		403	±12%	0.0614	0.003764
Confidence Interval	upper bound	354			
	lower bound	453			
	s	25			

Table A2-4. District water balance results for net pumping, CVWD, 1987-1992.

		1987	1988	1989	1990	1991	1992
		(1,000 ac-ft)					
Water Delivered to Coachella Canal		323	331	323	360	311	299
Coachella Canal losses (up to screens)		(34)	(34)	(34)	(34)	(34)	(34)
Coachella Deliveries to IID farms		(3)	(3)	(3)	(3)	(4)	(4)
Non-Ag Deliveries		(0)	(0)	(0)	(1)	(0)	(0)
Colorado Water Delivered to District		286	294	286	322	273	261
Canal and Reservoir Evaporation		(2)	(2)	(2)	(2)	(2)	(2)
CV storm drain flows & direct pumping		(117)	(117)	(111)	(110)	(104)	(101)
Rainfall on Irrig. land		20	15	4	2	17	33
Rainfall Evap. on Irr. land		(10)	(8)	(2)	(1)	(9)	(17)
Rainfall runoff- fallow land		1	1	0	0	1	1
Returnflow Non-Ag Discharges		5	5	5	5	5	5
Storm inflow (Whitewater river)		2	2	2	2	2	2
Subsurface flow to Drains (external sources)		1	1	1	1	1	1
Subsurface outflow to Salton Sea		(0)	(0)	(0)	(0)	(0)	(0)
Evap. from Drains, Rivers & Phreat.		(40)	(40)	(40)	(40)	(40)	(40)
Other District inflows-outflows		(141)	(144)	(143)	(143)	(129)	(118)
Irr. Water Crop Consum. Use. ET_w		225	222	234	228	212	208
Effective Precipitation	(oops!)						
Sprinkler Evaporation		2	2	3	3	3	2
Farm Pond Evaporation		3	3	3	3	3	3
Other farm evaporative losses		5	4	5	5	4	4
Other District inflows-outflows		141	144	143	143	129	118
Net district Supply		376	375	387	381	350	335
Net district Supply		376	375	387	381	350	335
Colorado Water Delivered to District		(286)	(294)	(286)	(322)	(273)	(261)
Net groundwater pumping		90	81	102	59	77	74
Confidence Interval	upper bound	49	44	62	28	42	39
	lower bound	132	119	142	90	113	110

Table A2-5 District-scale field water balance results for deep percolation and farm water supply (from district water balance on net pumping). CVWD, 1987-1992

		1987	1988	1989	1990	1991	1992
		(1.000 ac-ft)					
Colorado Water Delivered to Farms		282	286	307	315	275	262
Net groundwater pumping		90	81	102	59	77	74
Net Water Delivered to Ag users		372	367	409	374	352	337
Net Water Delivered to Ag users		372	367	409	374	352	337
Irr. Water Crop Consum. Use, ET_w		(225)	(222)	(234)	(228)	(212)	(208)
Sprinkler Evaporation		(2)	(2)	(3)	(3)	(3)	(2)
Farm Pond Evaporation		(3)	(3)	(3)	(3)	(3)	(3)
Other farm evaporative losses		(5)	(4)	(5)	(5)	(4)	(4)
Tailwater Runoff		(1)	(1)	(1)	(1)	(1)	(1)
Deep Percolation return flow		137	135	164	135	131	119
Deep Percolation return flow		137	135	164	135	131	119
Goundwater Recharge from Deep Perc		24	24	29	24	23	21
Deep Percolation		162	159	193	159	154	140
Confidence Interval	upper bound	108	109	139	113	107	93
	lower bound	215	209	246	205	201	187
Net groundwater pumping		90	81	102	59	77	74
Fish & Duck pond Evaporation		6	6	6	6	6	6
Goundwater Recharge from Deep Perc		24	24	29	24	23	21
Pumped deliveries		121	112	137	89	106	101
Confidence Interval	upper bound	73	70	92	58	67	61
	lower bound	168	154	182	120	145	142
Colorado Water Delivered to Farms		282	286	307	315	275	262
Pumped deliveries		121	112	137	89	106	101
Gross farm irrig water		403	398	444	404	381	364
Confidence Interval	upper bound	354	353	396	369	340	321
	lower bound	453	442	492	439	423	406

Table A2-6. District water balance for EI_w in CVWD: detailed calculations for 1987

	Volume (1,000 ac-ft)	Confidence Interval	Normalized C	Normalized C^2
Water Delivered to Coachella Canal	323	±4%	0.0226	0.000513
Coachella Canal losses (up to screens)	(34)	±15%	0.0089	0.000080
Coachella Deliveries to IID farms	(3)	±5%	0.0003	0.000000
Non-Ag Deliveries	(0)	±5%	0.0000	0.000000
Colorado Water Delivered to District	286	±5%	0.0243	0.000593
Colorado Water Delivered to District	286	±5%	0.0181	0.000328
Pumped deliveries	130	±40%	0.0678	0.004592
Fish & Duck pond Evaporation	(6)	±25%	0.0054	0.000029
Goundwater Recharge from Deep Perc	(25)	±60%	0.0199	0.000396
Net district Supply	384	±15%	0.0729	0.005316
Canal and Reservoir Evaporation	(2)	±20%	0.0012	0.000002
CV storm drain flows & direct pumping	(117)	±25%	0.0989	0.009775
Rainfall on Irrig land	20	±20%	0.0134	0.000180
Rainfall Evap. on Irr. land	(10)	±20%	0.0070	0.000049
Effective Rainfall	(7)	±20%	0.0046	0.000021
Rainfall runoff- fallow land	1	±30%	0.0007	0.000000
Returnflow Non-Ag Discharges	5	±50%	0.0090	0.000082
Storm inflow (Whitewater river)	2	±100%	0.0061	0.000037
Subsurface flow to Drains (external sources)	1	±100%	0.0017	0.000003
Subsurface outflow to Salton Sea	(0)	±100%	0.0007	0.000000
Evap. from Drains. Rivers & Phreat.	(40)	±50%	0.0676	0.004568
Other District inflows-outflows	(148)	±24%	0.1213	0.014716
Net district Supply	384	±15%	0.1237	0.015301
Other District inflows-outflows	(148)	±24%	0.0794	0.006299
Sprinkler Evaporation	(2)	±20%	0.0015	0.000002
Farm Pond Evaporation	(3)	±20%	0.0019	0.000004
Other farm evaporative losses	(5)	±100%	0.0100	0.000100
Irr. Water Crop Consum. Use	226	±29%	0.1473	0.021706
Confidence Interval — upper bound	160			
lower bound	293			
S	33			

Table A2-7. District-scale field water balance for deep percolation in CVWD: detailed calculations for 1987

	Volume (1,000 ac-ft)	Confidence Interval	Normalized C	Normalized C^2
Colorado Water Delivered to Farms	282	±5%	0.0174	0.000302
Pumped deliveries	130	±40%	0.0641	0.004105
Fish & Duck pond Evaporation	(6)	±25%	0.0054	0.000029
Water Delivered to Ag users	406	±13%	0.0666	0.004437
Water Delivered to Ag users	406	±13%	0.1594	0.025402
Irr. Water Crop Consum. Use	(226)	±29%	0.1965	0.038597
Sprinkler Evaporation	(2)	±20%	0.0013	0.000002
Farm Pond Evaporation	(3)	±20%	0.0017	0.000003
Other farm evaporative losses	(5)	±100%	0.0133	0.000178
Tailwater Runoff	(1)	±100%	0.0015	0.000002
Deep Percolation	170	±51%	0.2533	0.064184
Confidence Interval — upper bound	84			
lower bound	256			
S	43			

Table A2-8. Data used for water balance calculation for IID.

	1987	1988	1989	1990	1991	1992	Units
Reference ET	6.90	6.68	6.65	6.16	5.58	5.58	ft
Rainfall	0.23	0.13	0.09	0.21	0.41	0.46	ft
Delivery to AA Canal at Pilot Knob	3,091	3.279	3.377	3,420	3.211	2,876	1,000 ac-ft
Water Delivered to Coachella Canal	320	325	351	359	308	297	1,000 ac-ft
Deliveries to IID farms above EHL	5	5	5	5	5	5	1,000 ac-ft
Non-Ag Deliveries	64	62	66	70	71	72	1,000 ac-ft
Alamo River flow to sea	512	559	594	618	594	546	1,000 ac-ft
New River flow to sea	493	489	431	431	411	397	1,000 ac-ft
Direct Inflow to sea	99	100	96	91	88	81	1.000 ac-ft
Surface inflow from Mexico	253	229	155	135	133	145	1.000 ac-ft
Colorado Water Delivered to Farms	2,322	2,493	2.577	2,611	2,449	2,106	1.000 ac-ft
Est. Tailwater	387	419	435	439	409	353	1.000 ac-ft
Net Irrigated Land	456	461	464	469	468	460	1,000 ac
Est. sprinkler Acreage	116	119	134	148	122	99	1,000 ac

Table A2-9. District water balance for ET_w in IID: detailed calculations for 1987.

	Volume (1,000 ac-ft)	Confidence Interval	Normalized C	Normalized C^2
Delivery to AA Canal at Pilot Knob	3,091	±3%	0.0178	0.000317
Water Delivered to Coachella Canal	(320)	±4%	0.0025	0.000006
Seepage between PK and EHL	(94)	±15%	0.0027	0.000007
Evaporation between PK and EHL	(5)	±10%	0.0001	0.000000
Deliveries to IID above EHL	(5)	±5%	0.0000	0.000000
Non-Ag Deliveries	(64)	±5%	0.0006	0.000000
Colorado Water Delivered to District	2.602	±4%	0.0182	0.000331
Colorado Water Delivered to District	2.602	±4%	0.0182	0.000331
Pumped deliveries	0			
Goundwater Recharge from Deep Perc	0			
Net district Supply	2.602	±4%	0.0182	0.000331
Canal and Reservoir Evaporation	(24)	±20%	0.0026	0.000007
Alamo River flow to sea	(512)	±8%	0.0225	0.000505
New River flow to sea	(493)	±8%	0.0216	0.000468
Direct Inflow to sea	(99)	±10%	0.0054	0.000030
Surface inflow from Mexico	253	±10%	0.0139	0.000192
Rainfall on Irrig. land	103	±20%	0.0112	0.000126
Rainfall Evap. on Irr. land	(53)	±20%	0.0058	0.000034
Effective Rainfall	(35)	±20%	0.0038	0.000015
Rainfall runoff- non-Ag land	0	±20%	0.0001	0.000000
Returnflow Non-Ag Discharges	14	±30%	0.0023	0.000005
Storm Inflow (Mesa)	3	±30%	0.0005	0.000000
Subsurface flow to Drains (external sources)	20	±30%	0.0033	0.000011
Subsurface Outflow to Salton Sea	(1)	±40%	0.0002	0.000000
Evap. from Drains, Rivers & Phreat.	(87)	±20%	0.0096	0.000091
Other District inflows-outflows	(912)	±8%	0.0385	0.001484
Net district Supply	2,602	±4%	0.0287	0.000826
Other District inflows-outflows	(912)	±8%	0.0213	0.000455
Sprinkler Evaporation	(9)	±25%	0.0007	0.000000
Farm Pond Evaporation	(0)	±25%	0.0000	0.000000
Other farm evaporative losses	(33)	±100%	0.0100	0.000100
Irr. Water Crop Consum. Use	1,648	±7%	0.0372	0.001381
Confidence Interval — Upper bound	1,525			
Lower bound	1.770			
S	61			

Table A2-10 District-scale field water balance for deep percolation in IID: detailed calculations for 1987

		Volume (1,000 ac-ft)	Confidence Interval	Normalized C	Normalized C^2
Colorado Water Delivered to Farms		2,322	±5%	0.0250	0.000625
Pumped deliveries		0			
Water Delivered to Ag users		2,322	±5%	0.0250	0.000625
Water Delivered to Ag users		2.322	±5%	0.2370	0.056158
Irr. Water Crop Consum. Use		(1.648)	±7%	0.2500	0.062483
Sprinkler Evaporation		(9)	±25%	0.0045	0.000020
Farm Pond Evaporation		(0)	±25%	0.0002	0.000000
Other farm evaporative losses		(33)	±100%	0.0673	0.004524
Tailwater Runoff		(387)	±20%	0.1581	0.025008
Deep Percolation		245	±77%	0.3850	0.148193
Confidence Interval	Upper bound	56			
	Lower bound	434			
	S	94			

Table A2-11 District water balance results for ETiw in IID, 1987-1992

		1987	1988	1989	1990	1991	1992
		(1.000 ac-ft)					
Delivery to AA Canal at Pilot Knob		3,091	3.279	3,377	3,420	3.211	2,876
Water Delivered to Coachella Canal		(320)	(325)	(351)	(359)	(308)	(297)
Seepage between PK and EHL		(94)	(94)	(94)	(94)	(94)	(94)
Evaporation between PK and EHL		(5)	(5)	(5)	(5)	(4)	(4)
Deliveries to IID above EHL		(5)	(5)	(5)	(5)	(5)	(5)
Non-Ag Deliveries		(64)	(62)	(66)	(70)	(71)	(72)
Colorado Water Delivered to District		2.602	2,787	2,855	2.886	2,728	2.403
Colorado Water Delivered to District		2.602	2.787	2.855	2.886	2.728	2,403
Pumped deliveries		0	0	0	0	0	0
Goundwater Recharge from Deep Perc		0	0	0	0	0	0
Net district Supply		2.602	2,787	2,855	2,886	2.728	2.403
Canal and Reservoir Evaporation		(24)	(23)	(23)	(21)	(19)	(19)
Alamo River flow to sea		(512)	(559)	(594)	(618)	(594)	(546)
New River flow to sea		(493)	(489)	(431)	(431)	(411)	(397)
Direct Inflow to sea		(99)	(100)	(96)	(91)	(88)	(81)
Surface inflow from Mexico		253	229	229	155	135	133
Rainfall on Irrig land		103	60	43	95	185	209
Rainfall Evap. on Irr land		(53)	(31)	(22)	(49)	(96)	(109)
Effective Rainfall		(35)	(20)	(14)	(32)	(63)	(71)
Rainfall runoff- non-Ag land		0	0	0	0	1	1
Returnflow Non-Ag Discharges		14	14	14	14	14	14
Storm Inflow (Mesa)		3	3	3	3	3	3
Subsurface flow to Drains (external sources)		20	20	20	20	20	20
Subsurface Outflow to Salton Sea		(1)	(1)	(1)	(1)	(1)	(1)
Evap. from Drains, Rivers & Phreat.		(87)	(84)	(84)	(78)	(71)	(70)
Other District inflows-outflows		(912)	(982)	(957)	(1,034)	(985)	(914)
Net district Supply		2.602	2.787	2,855	2,886	2,728	2,403
Other District inflows-outflows		(912)	(982)	(957)	(1.034)	(985)	(914)
Sprinkler Evaporation		(9)	(9)	(10)	(11)	(9)	(7)
Farm Pond Evaporation		(0)	(0)	(0)	(0)	(0)	(0)
Other farm evaporative losses		(33)	(35)	(37)	(36)	(34)	(29)
Irr Water Crop Consum. Use		1,648	1,761	1.851	1.805	1,700	1.452
Confidence Interval	Upper bound	1.525	1.634	1,722	1,674	1,571	1.332
	Lower bound	1,770	1,887	1,979	1.935	1,828	1.572

Table A2-12. District-scale field water balance results for deep percolation (from district water balance on EI_w), IID, 1987-1992.

		1987	1988	1989	1990	1991	1992
		(1,000 ac-ft)					
Colorado Water Delivered to Farms		2,322	2,493	2,577	2,611	2,449	2,106
Pumped deliveries		0	0	0	0	0	0
Water Delivered to Ag users		2,322	2,493	2,577	2,611	2,449	2,106
Water Delivered to Ag users		2,322	2,493	2,577	2,611	2,449	2,106
Irr. Water Crop Consum. Use		(1,648)	(1,761)	(1,851)	(1,805)	(1,700)	(1,452)
Sprinkler Evaporation		(9)	(9)	(10)	(11)	(9)	(7)
Farm Pond Evaporation		(0)	(0)	(0)	(0)	(0)	(0)
Other farm evaporative losses		(33)	(35)	(37)	(36)	(34)	(29)
Tailwater Runoff		(387)	(419)	(435)	(439)	(409)	(353)
Deep Percolation		245	269	244	319	296	265
Confidence Interval	Upper bound	56	70	38	112	98	88
	Lower bound	434	469	449	527	495	442

APPENDIX 3

EVALUATING EFFECTIVE RAINFALL
IN CVWD

APPENDIX 3

EVALUATING EFFECTIVE RAINFALL IN CVWD

by
Marvin E. Jensen
01 Oct 93

INTRODUCTION

In my previous report (Effective Precipitation, 20-Sep-93), I summarized several procedures developed for estimating effective precipitation (the SCS-USDA method, SCS, 1970; and Hershfield, 1964) and reviewed several other papers on effective precipitation (Kopec et al., 1984; Nieber and Patwardhan, 1988; and Patwardhan et al., 1990). In this report, I summarize an evaluation of effective rainfall in the Coachella Valley Water District (CVWD) using a combination of methods.

ESTIMATING RAINFALL RUNOFF

Methods for estimating runoff from small watersheds for use in hydrological models have been summarized in monographs edited by Haan et al. (1982) and Hanks and Ritchie (1991). Specific aspects surface runoff, storage and routing, including the SCS-USDA method of estimating the abstraction of precipitation were described by Huggins (1982). Williams (1991) summarized adaptations of the SCS-USDA method for use in modeling.

PROCEDURES

Rainfall Interception

No specific data or equations for rainfall interception by agricultural crops were found in a brief search of agronomic literature. Therefore, the method used by Nieber and Patwardhan (1988) was used in this analysis. Their equation converted to inches of rainfall is:

$$I = 0.03\,TP\left(\frac{R}{0.5\,R + 0.06}\right) \tag{1}$$

where I = the interception of rainfall by crops, R is rainfall and TP is days since planting. I is limited to 0.2 S. For this analysis, the date of planting of annual crops was assumed to be 15 October.

Rainfall Runoff

The SCS rainfall-runoff relation was used to estimate runoff:

$$Q = \frac{(R - I_a)^2}{R - I_a + S} = \frac{(R - 0.2S)^2}{R + 0.8S} \tag{2}$$

where Q is the cumulative direct runoff, R is the cumulative rainfall and S is the maximum potential retention. The initial abstraction (I_a) in a typical storm is I_a = 0.2 S. The value of the maximum surface retention after runoff begins, S, in inches is obtained from the SCS Curve Number (CN):

$$S = \frac{1000}{CN} - 10 \tag{3}$$

For this analysis, soil type "D" was used. Type D soil is classified as having a very slow infiltration, i.e., less than 0.05 in/h when wet. Rainfall events for the period 1986-92 at Thermal, California were used. When rains occurred on consecutive days, they were called Day 1, Day 2 and Day 3 rains. For Day 1 rains, Condition II for average conditions was used. For Day 2 and Day 3 rains, Condition III (wet) was assumed.

The antecedent moisture Condition I is for dry soils, as prior to or after plowing or cultivating. Condition II is for average conditions. Condition III is for saturated soil due to heavy rainfall (or light rainfall with low temperature 5 days prior to a storm).

The curve number selected was CN = 89 for row crops, Condition II, and CN = 96 for row crops, Condition III. The maximum retention (S) for these two conditions was 1.24 in. for Condition II and 0.42 in. for Condition III.

Non-Beneficial Evaporation after Rains

After a rain, or several days of rains, the soil surface is wet and evapotranspiration is greater than that occurring just before the rain. The method developed at Kimberly Idaho of estimating the increase in evaporation due to rains or irrigations was used as summarized on page 118 of ASCE Manual 70 (Jensen et al., 1990):

$$E+ = 0.35\,[t_d + 1.5)]\,[K_1 - K_a K_{cb}]\,ET_o \tag{4}$$

where E+ is the increase in ET, t_d is the number of days after a rain usually required for soil surface to appear visually dry, which for clay loam soils may be 7 days or more. For sandy soils, t_d may be 3 days or less. For this analysis, a value of 7 was used. The maximum rate of ET after a rain is determined by the value of K_l, which was set at 1.2 for use with ET_o. K_{cb} is the basal crop coefficient and K_a is the relative effect of reduced soil water. The resulting crop coefficient is $K_c = K_a K_{cb}$. For this analysis, a weighted average crop coefficient was used. The weighted average monthly K_c values were calculated using the distribution of major crops in CVWD.

JMLord's crop coefficients for alfalfa-based reference ET were adapted for use with ET_o by multiplying his coefficients by 1.2 based on the relationship $ET(alf)/ET_o = 1.2$. Therefore, $K_{co} = 1.2 K_{ca}$ where K_{co} is the crop coefficient to be used with ET_o and K_{ca} is the corresponding coefficient to be used with alfalfa-based reference ET. For rainfall less than that obtained from Eq. 4, the increase in evaporation was limited to the amount of rainfall.

The distribution of rains during the period 1986-92 was derived from climatological data provided by CVWD for Thermal, California. CIMIS reference ET values (ET_o) for Thermal were obtained from the report by Boyle (Styles, 1993) for the years 1987-90. Average monthly ET_o values were used for 1986, 1991 and 1992. Since there was little rainfall from May through August, the analysis was carried out for the period September-April.

RESULTS

Rainfall Events

The number of single day storms for the September-April period was 109. The number of 2-day storms was 25. Only 5 storms produced rainfall for three consecutive days. The average rainfall for Day 1, Day 2 and Day 3 is summarized in Fig. 1.

Most of the rainfall occurred on Day 1 and Day 2 except in December. The distribution of rainfall events by depth increments and days is summarized for months September-April in Figures 2-9. Most of the rains provided only 0 to 0.2-inch of rainfall. Only a few rains exceeded 0.8-inch in February.

Adjusted Crop Coefficients

The mean monthly JMLord's crop coefficients for major crops grown in CVWD adjusted for use with ET_o reference ET are summarized in Figures 10a, 10b and 10c.

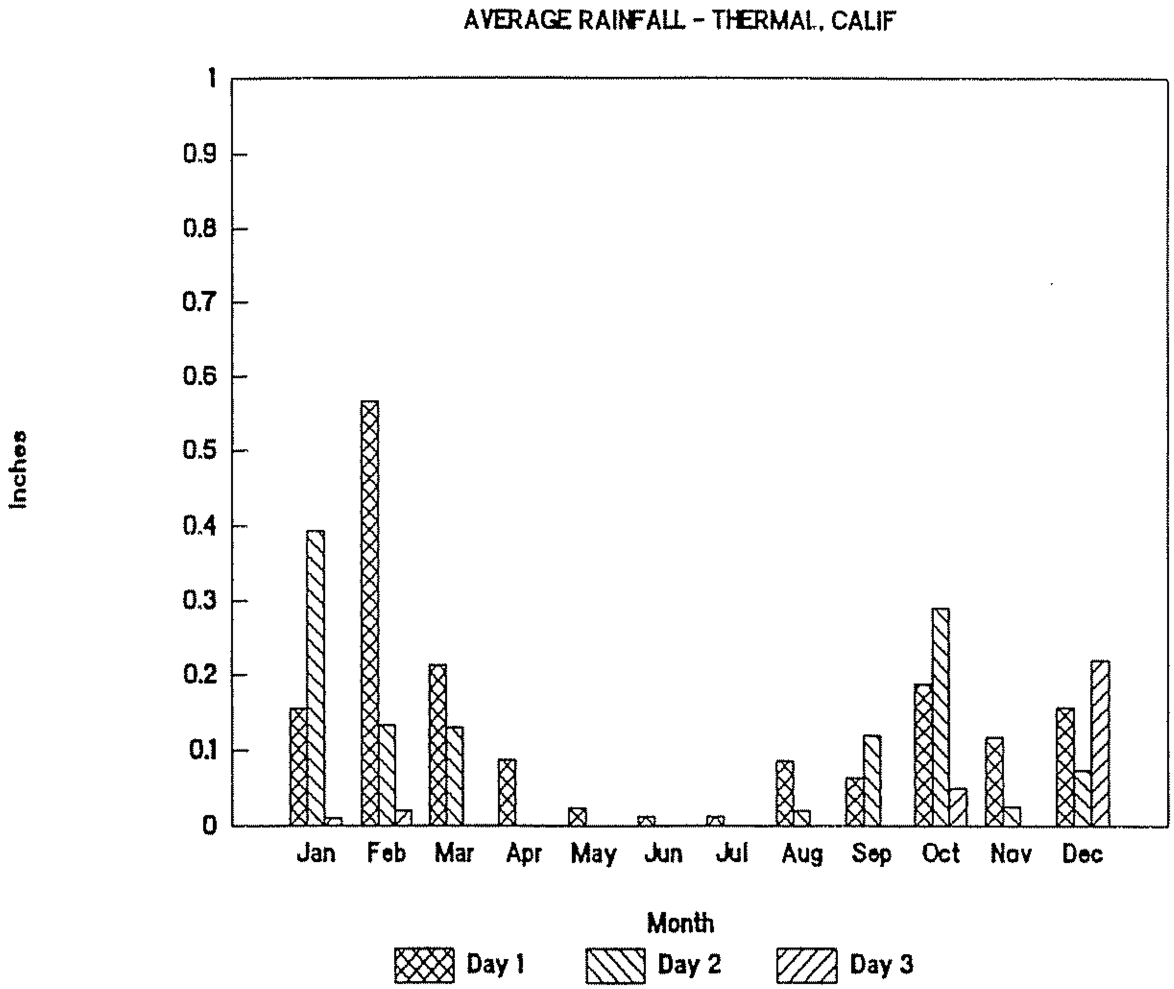


Fig. 1. Average precipitation for Day 1, Day 2 and Day 3 storms at Thermal, California for the period 1986-92.

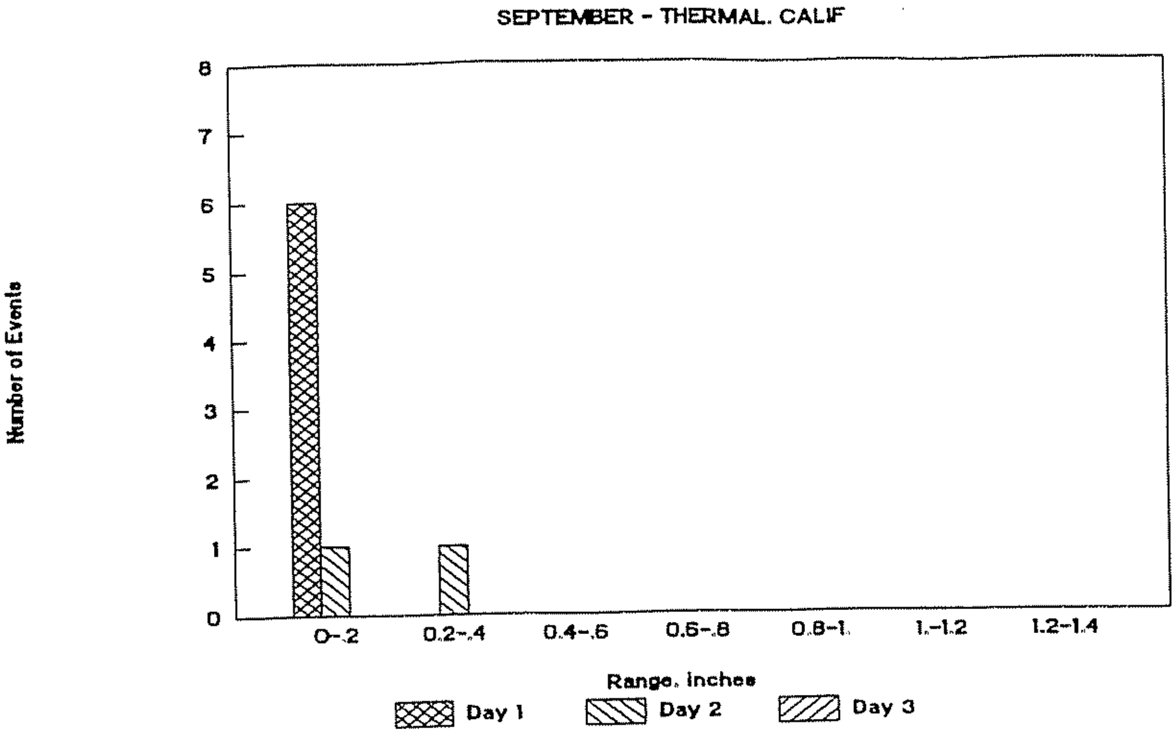


Fig. 2. Distribution of rainfall for Day 1, Day 2, and Day 3 for September at Thermal, California for the period 1986-92.

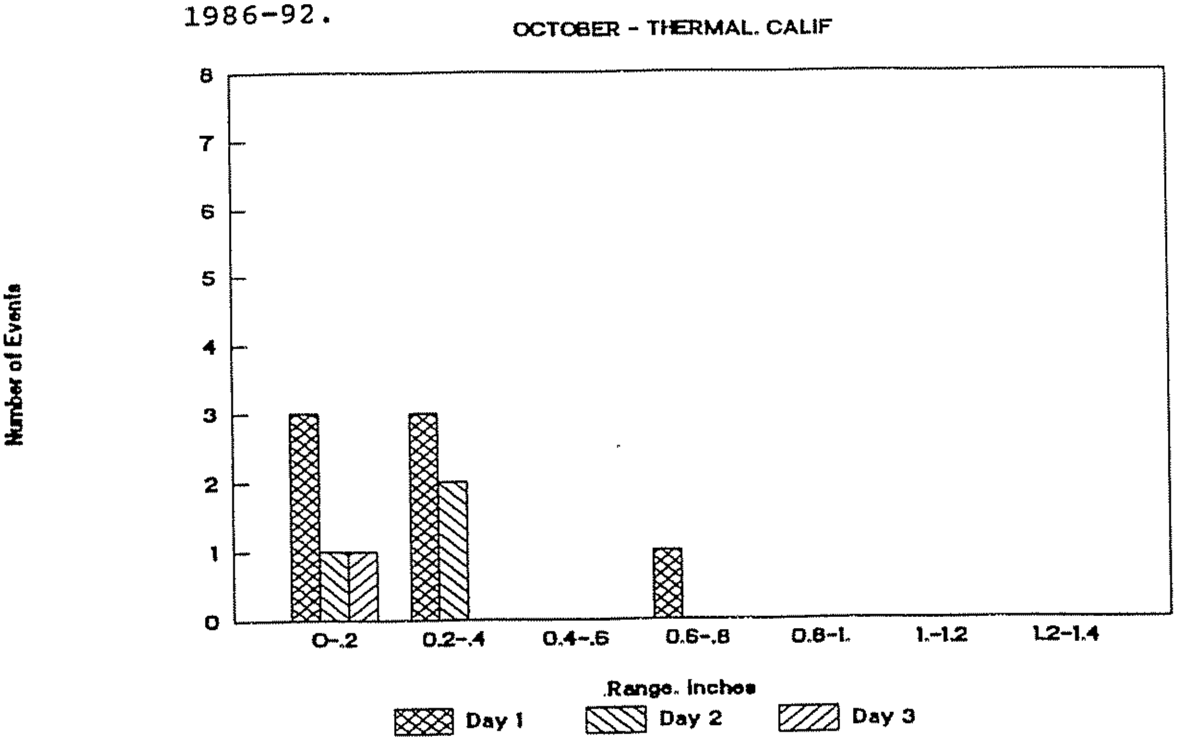


Fig. 3. Distribution of rainfall for Day 1, Day 2, and Day 3 for October at Thermal, California for the period 1986-92.

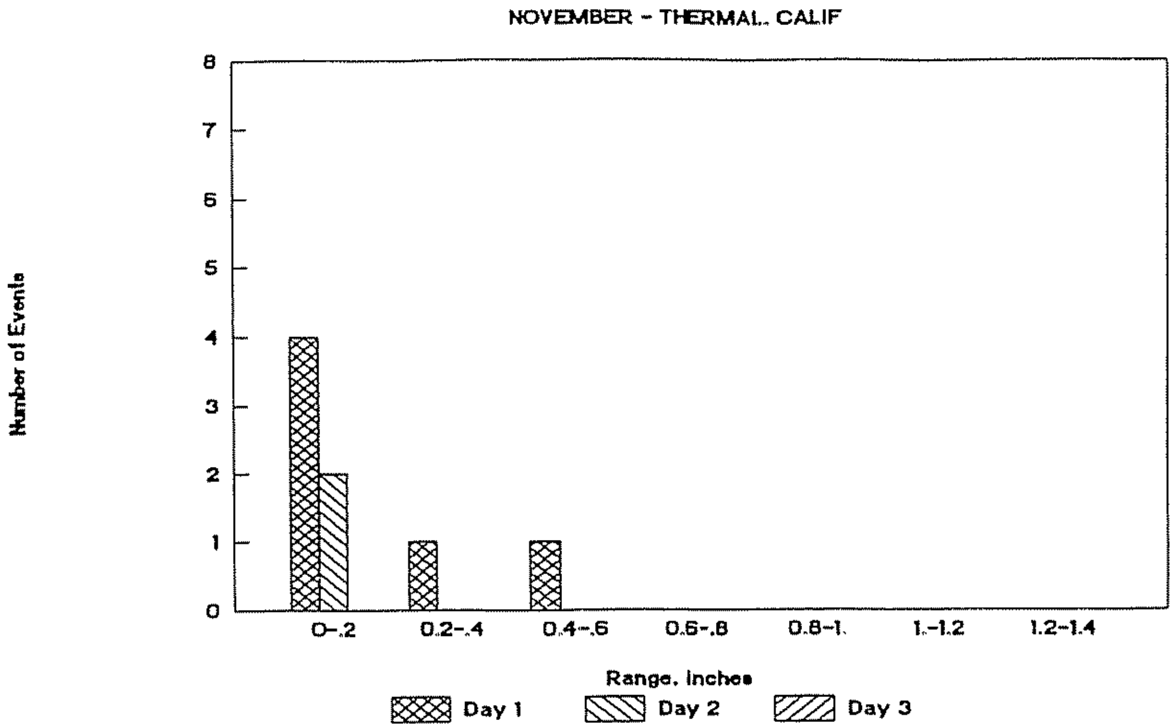


Fig. 4. Distribution of rainfall for Day 1, Day 2, and Day 3 for November at Thermal, California for the period 1986-92.

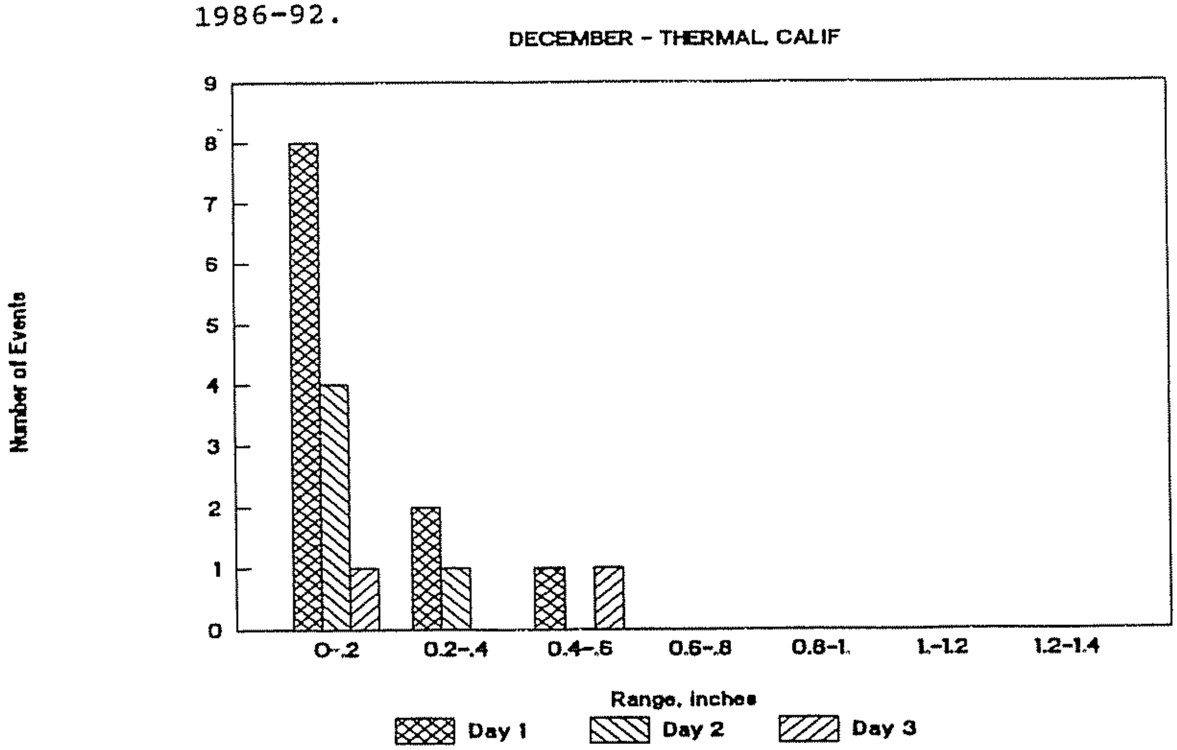


Fig. 5. Distribution of rainfall for Day 1, Day 2, and Day 3 for December at Thermal, California for the period 1986-92.

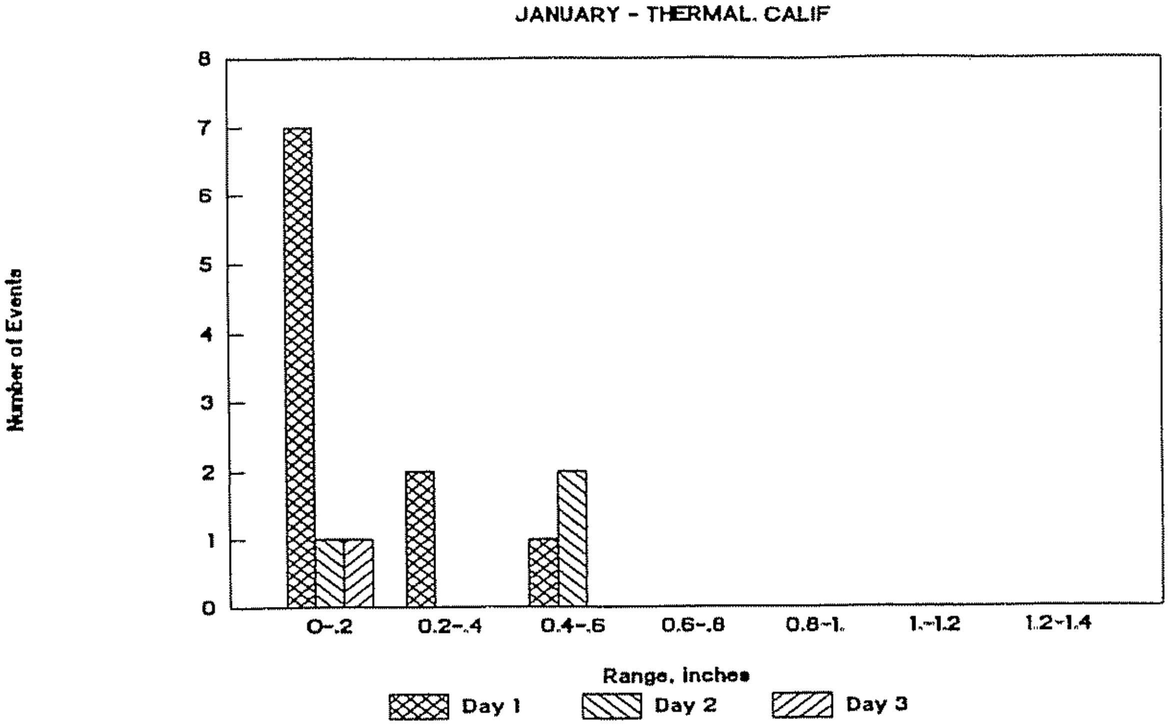


Fig. 6. Distribution of rainfall for Day 1, Day 2, and Day 3 for January at Thermal, California for the period 1986-92.

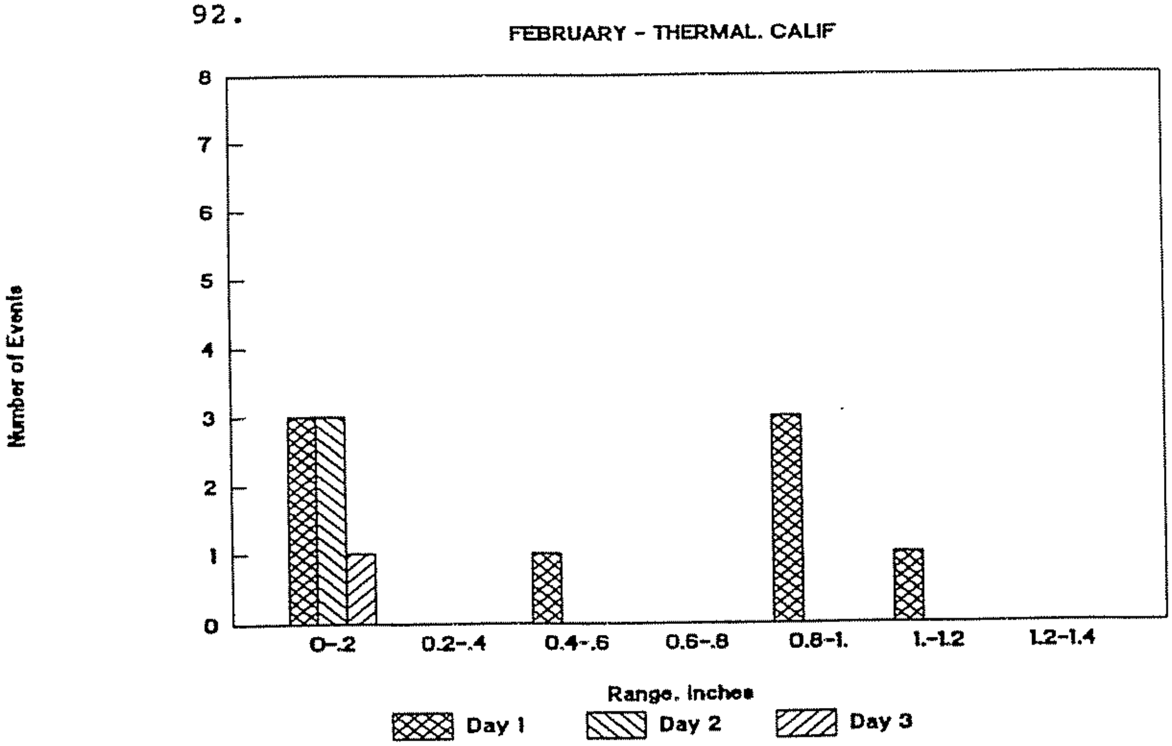


Fig. 7. Distribution of rainfall for Day 1, Day 2, and Day 3 for February at Thermal, California for the period 1986-92.

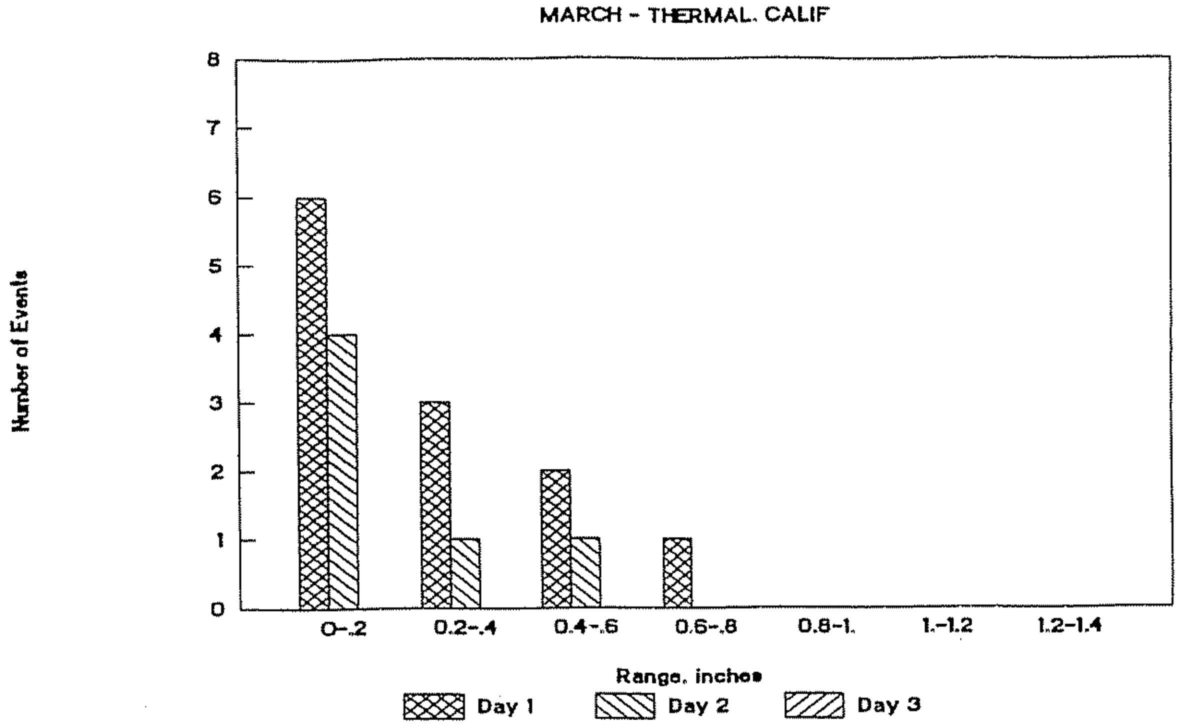


Fig. 8. Distribution of rainfall for Day 1, Day 2, and Day 3 for March at Thermal, California for the period 1986-92.

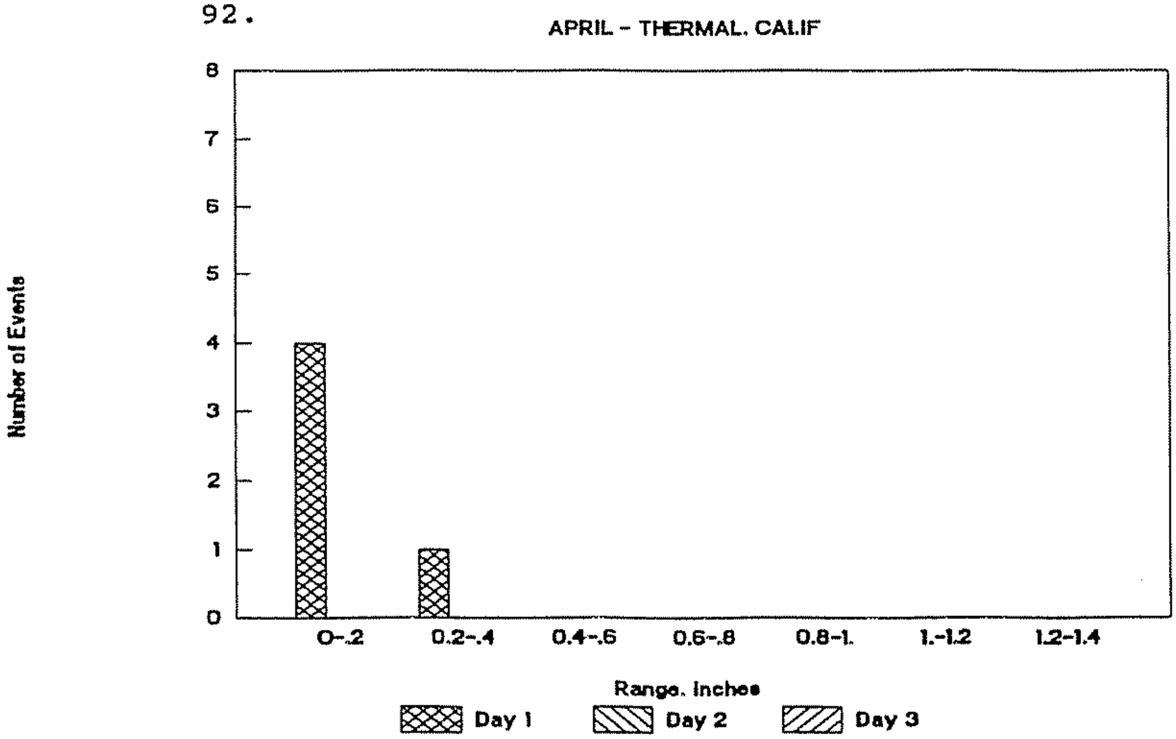


Fig. 9. Distribution of rainfall for Day 1, Day 2, and Day 3 for April at Thermal, California for the period 1986-92.

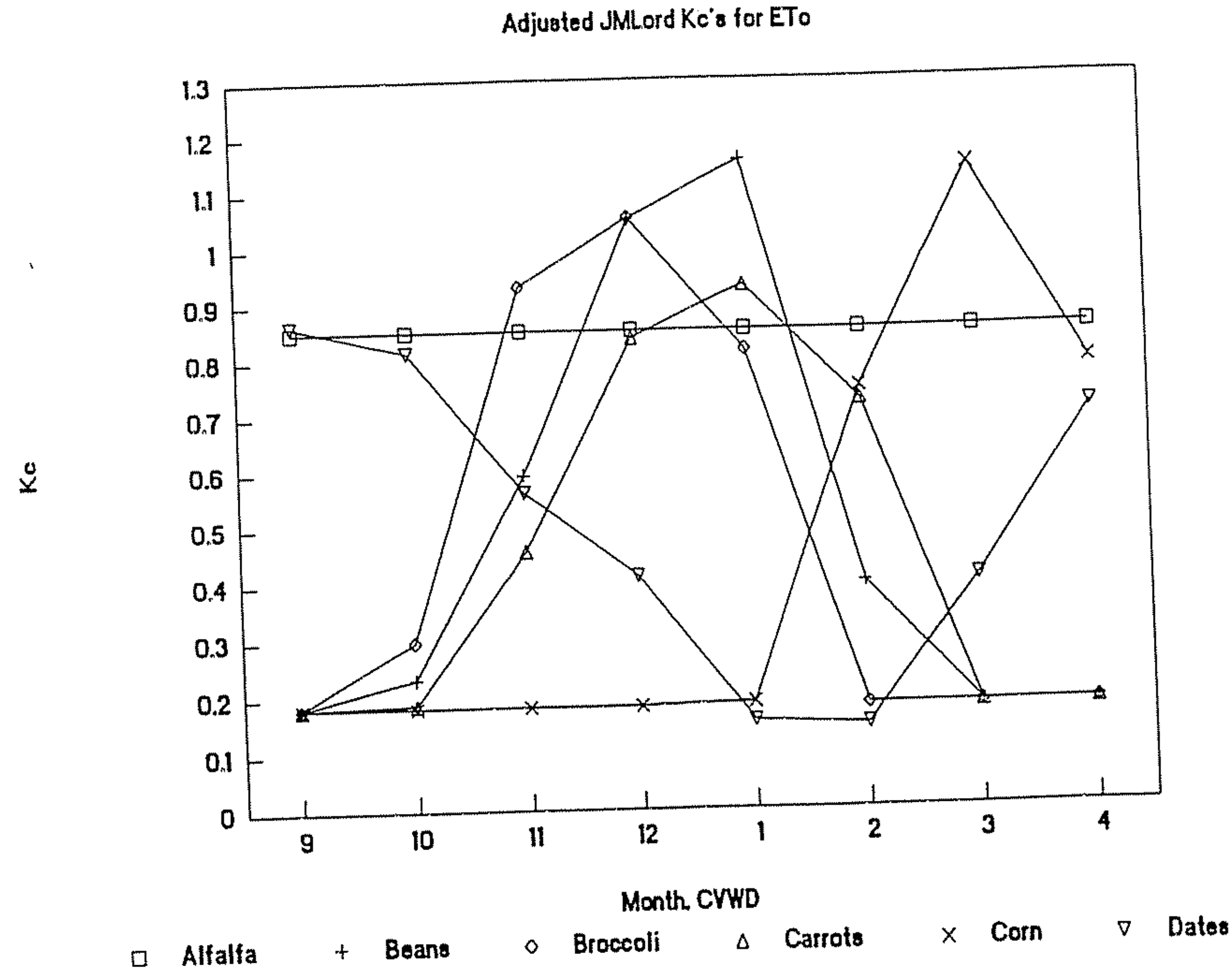
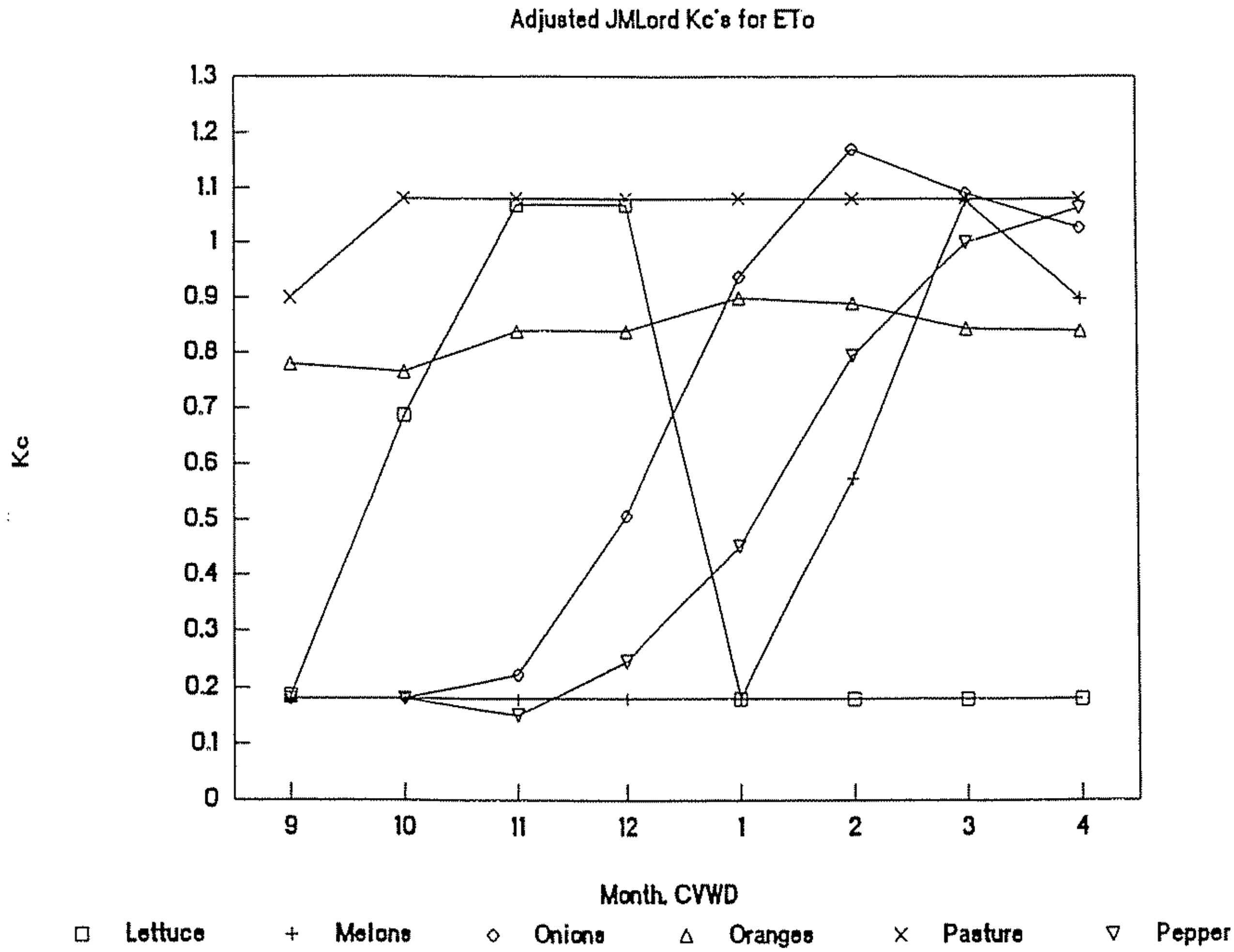
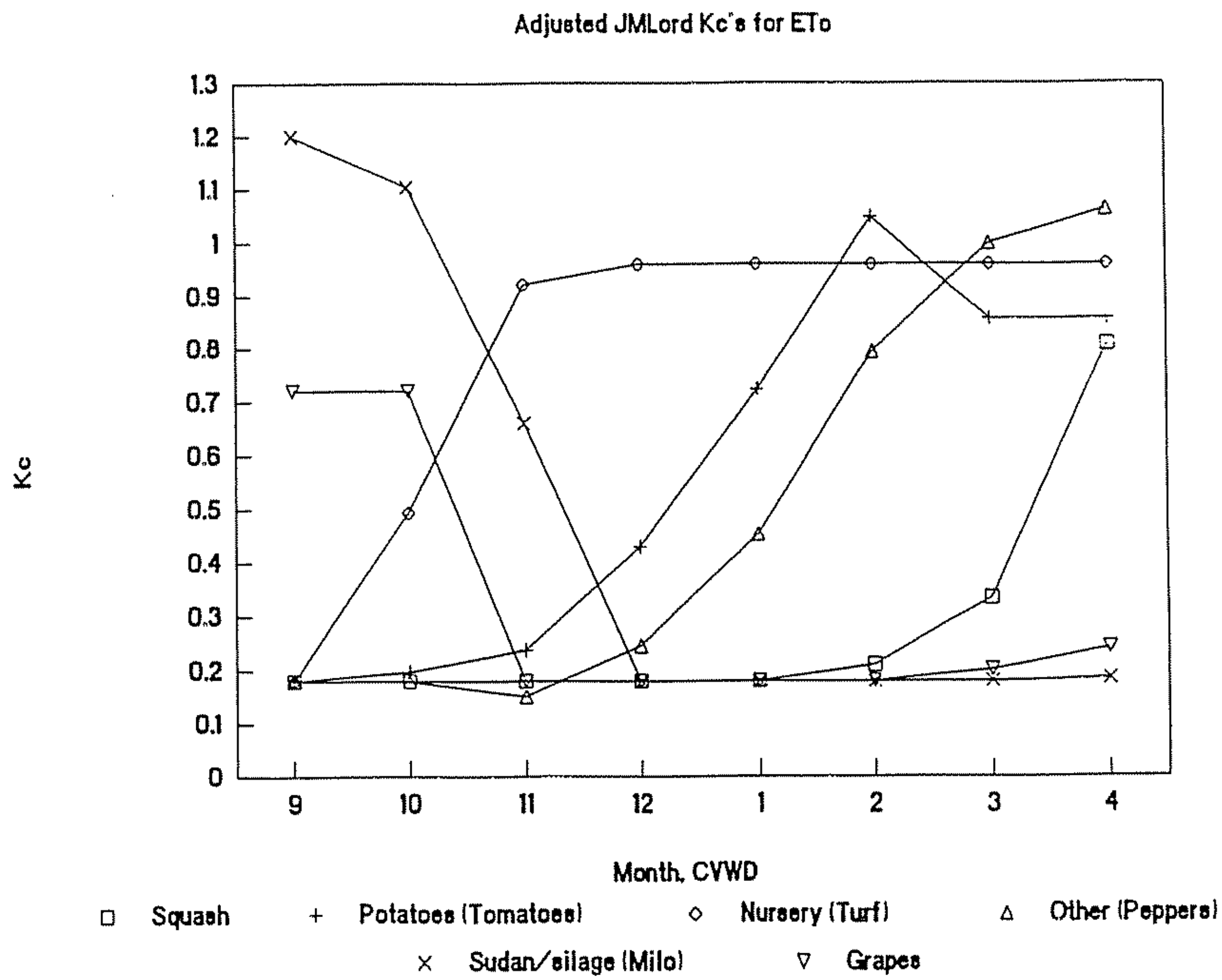


Fig. 10a. Mean monthly crop coefficients adjusted from JMLord's alfalfa-based reference ET coefficients for use with ET_o in the CVWD.



10b. Mean monthly crop coefficients adjusted from JMLord's alfalfa-based reference ET coefficients for use with ET_o in the CVWD.



10c. Mean monthly crop coefficients adjusted from JMLord's alfalfa-based reference ET coefficients for use with ET_o in the CVWD.

The dates of planting, full cover and harvest used in the analysis are summarized in Table 1. Several minor adjustments of the "interval" were needed so that the harvest date minus "4 x interval" did not precede the effective cover date.

The average monthly coefficients for the individual major crops are summarized in Table 2. The weighted average crop coefficient for each month is summarized in the last row of Table 2.

Estimated Runoff and Increased Evaporation

A summary of the results obtained from estimating interception of rainfall, runoff and increased evaporation following rainfall is presented in Table 3. The estimated total runoff was 2.8 inches for the 6-year period or 14 percent of the total rainfall. The estimated evaporation of rainfall from that intercepted by crops plus that which wetted the soil was 52 percent. Except for November, the effective rainfall ranged from 40 to 50 percent for the period October through February. It decreased to 20 percent in March.

The average annual effective rainfall was 34 percent of the total. Styles (1990) estimated 30 percent. The details of the computations are presented in Appendix A3-A.

The average percentage of effective rainfall is presented in Fig. 11. Rainfall during the summer months is essentially non-effective because of small amounts and high evaporation rates.

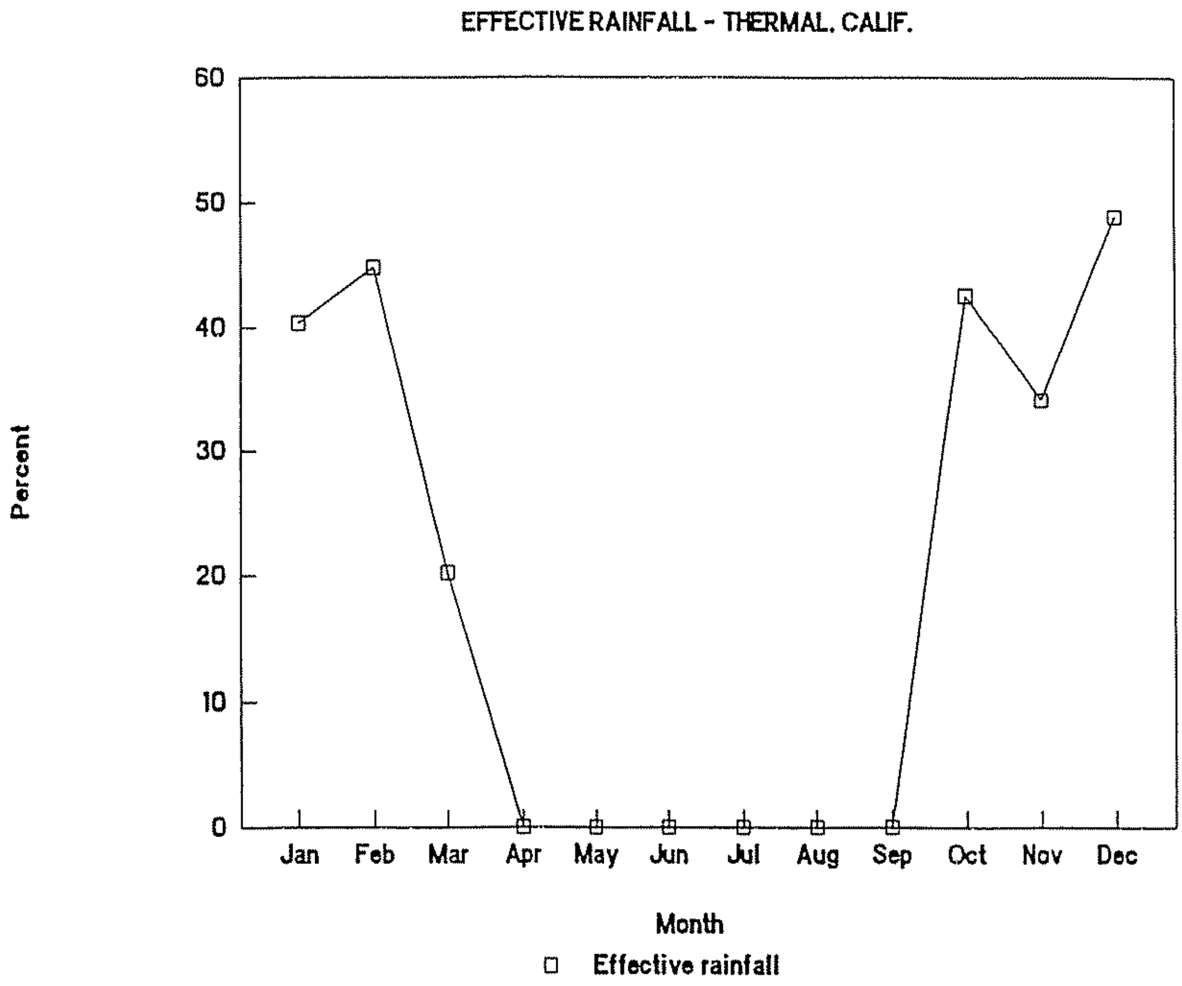


Fig. 11. Average effective rainfall based on Thermal, California rainfall data for 1986-1992.

Table 1. Distribution of major crops and estimated planting, full cover and harvest dates in the CVWD.

Crop	acres	Inter-val 1)	Planting Date	Planting CD	Full cover Date	Full cover CD	Harvest Date	Harvest CD	Comment
FIELD CROPS:									
Alf. hay	2,130	20	01-Sep	244	06-Jun	528	31-Aug	608	Season
I. pasture	1,555	84	01-Sep	244	29-Sep	272	31-Aug	608	Season
Sudan/sil.	2,940	25	14 Apr	104	07-Aug	219	15-Nov	319	Milo Kc
Other	1,267	79	14 Apr	104	03-Jan	3	15-Nov	319	Pasture Kc
FRUIT CROPS:									
Dates	5,689	40	01-Jan	1	24-Jul	205	31-Dec	365	
Citrus	13,094	52	01-Jan	1	06-Jun	157	31-Dec	365	Oranges Kc
Grapes	12,008	30	01-Mar	60	03-Jul	184	31-Oct	304	
Other	454	40	01-Mar	60	24-May	144	31-Oct	304	Peaches Kc
TRUCK CROPS:									
Beans	892	15	01-Oct	274	31-Dec	365	01-Mar	425	
Broccoli	810	15	01-Oct	274	03-Dec	337	01-Feb	397	
Carrots	1,140	20	14-Oct	287	25-Dec	359	15-Mar	439	
Corn, sw	4,582	15	14-Jan	379	17-Mar	441	16-May	501	
Lettuce	2,596	25	14-Sep	257	12-Sep	255	21-Dec	355	
Okra	414	20	01-Nov	305	10-Jan	375	31-Mar	455	Soybean Kc
Onion, dry	588	25	01-Nov	305	04-Feb	400	15-May	500	
Peppers	1,245	15	01-Nov	305	01-Apr	456	15-May	516	
Potatoes	870	15	01-Nov	305	16-Mar	440	15-May	500	
Squash	647	15	01-Feb	397	01-May	486	30-Jun	546	
Watermelon	724	20	01-Jan	1	12-Mar	436	31-Dec	516	Melon Kc
Misc. veg.	786	15	01-Nov	305	01-Apr	456	15-May	516	Pepper Kc
Nursery	790	5	01-Oct	274	10-Apr	465	01-Feb	485	Turf Kc
Other	2,077	15	01-Nov	305	01-Apr	456	15-May	516	Pepper Kc

1) Interval refers to the days in periods 1-4 after full cover (JMLord's Crop Coefficients).

Table 2. Average crop coefficients for major crops in the CVWD for use with CIMIS values of Eto in estimating effective rainfall.

Crop	Area, acres	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	Cmt.
						Monthly Kc for ETo				
FIELD CROPS:										
Alf. hay	2,130	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	1)
I. pasture	1,555	1.08	0.90	1.08	1.08	1.08	1.08	1.08	1.08	1)
Sudan/sil.	2,940	1.10	0.66	0.18	0.18	0.18	0.18	0.18	0.18	2)
Other	1,267	0.90	1.08	1.08	1.08	1.08	1.08	1.08	1.08	3)
FRUIT CROPS:										
Dates	5,689	0.86	0.81	0.56	0.41	0.15	0.15	0.40	0.71	
Citrus	13,094	0.78	0.83	0.84	0.84	0.90	0.89	0.84	0.84	4)
Grapes	12,008	0.72	0.72	0.18	0.18	0.18	0.18	0.20	0.24	
Other	454	0.90	0.89	0.18	0.18	0.18	0.18	0.11	0.61	5)
TRUCK CROPS:										
Bean	892	0.18	0.23	0.59	1.05	1.15	0.40	0.18	0.18	
Broccoli	810	0.18	0.30	0.93	1.05	0.81	0.18	0.18	0.18	
Carrots	1,140	0.18	0.19	0.46	0.84	0.93	0.72	0.18	0.18	
Corn, sw	4,582	0.18	0.18	0.18	0.18	0.18	0.75	1.14	0.79	
Lettuce	2,596	0.19	0.69	1.07	1.07	0.18	0.18	0.18	0.18	
Okra	414	0.18	0.18	0.23	0.73	1.14	1.14	0.70	0.18	6)
Onion, dry	588	0.18	0.18	0.22	0.51	0.94	1.17	1.09	1.03	
Peppers	1,245	0.18	0.18	0.15	0.25	0.45	0.80	1.00	1.06	
Potatoes	870	0.18	0.20	0.24	0.43	0.72	1.05	0.86	0.86	
Squash	647	0.18	0.18	0.18	0.18	0.18	0.33	0.81	0.21	
Watermelon	724	0.18	0.18	0.18	0.18	0.18	0.57	1.08	0.90	7)
Misc. veg.	786	0.18	0.18	0.15	0.25	0.45	0.80	1.00	1.06	8)
Nursery	790	0.18	0.49	0.92	0.96	0.96	0.96	0.96	0.96	9)
Other	2,077	0.18	0.18	0.15	0.25	0.45	0.80	1.09	1.06	10)
Total	57,298									
Total Ac x Kc		35,319	36,053	29,245	30,318	28,808	32,109	35,354	35,512	
Average Kc		0.62	0.63	0.51	0.53	0.50	0.56	0.62	0.62	

1) Season
2) Milo Kc
3) Pasture Kc
4) Oranges Kc
5) Peaches Kc
6) Soybean Kc
7) Melon Kc
8) Pepper Kc
9) Turf Kc
10) Pepper Kc

Table 3. Summary of Day 1, Day 2, and Day 3 rains, and estimated runoff and increased evaporation following rains for Thermal, California, 1986-92.

	Rain Storms				
	Day 1	Day 2	Day 3	Day 4	Total
Total rainfall, inches	16.3	3.9	0.5	0	20.7
Rainfall events	109	25	5	0	139
Runoff (RO),inches	1.65	1.0	0.15	0	2.8
Runoff (RO), percent	10	26	30	---	14
Increased evaporation (E+), inches					10.8
Increased evaporation (E+), percent					52
Total losses (RO + E+), inches					13.6
Total losses (RO + E+), percent					66
Effective rainfall (ER), inches					7.1
Effective rainfall (ER), percent					34

Summary by Months - total, 1986-1992

Month	Rain	Runoff	E+	RO + E+	ER, in.	ER, %
January	2.74	0.53	1.11	1.63	1.11	40
February	5.39	1.15	1.83	2.97	2.42	45
March	3.76	0.45	2.55	3.00	0.76	20
April	0.70	0.00	0.70	0.70	0.00	0
May	0.19	0.00	0.19	0.19	0.00	0
June	0.09	0.00	0.09	0.09	0.00	0
July	0.10	0.00	0.10	0.10	0.00	0
August	0.54	0.00	0.54	0.54	0.00	0
September	0.81	0.00	0.81	0.81	0.00	0
October	2.61	0.37	1.13	1.50	1.11	43
November	1.11	0.04	0.69	0.73	0.38	34
December	2.69	0.28	1.10	1.38	1.31	49
Annual	20.73	2.81	10.83	13.64	7.09	
Percent	100	14	52	66	34	

Rainfall-Irrigation Interaction

In an analysis of factors affecting the ordering of water in the IID, Gutwein and Lang (1993) showed that rainfall amounts, though small, greatly affected the demand for water. They reported a sharp drop in water orders following rainfall events. On an annual basis, water diversions expressed on a depth basis decreased by a factor of 2.3 times the annual rainfall amount. Therefore, reduced water orders appear to over-compensate for rainfall. However, this relationship does not reflect the decrease in evaporative demand associated with a rainy period.

SUMMARY AND CONCLUSIONS

Most of the rainfall occurred on Day 1 and Day 2 of storm periods except in December. Most of the rains provided only 0 to 0.2-inch of rainfall. Only a few rains exceeded 0.8-inch in February.

The estimated total runoff was 2.8 inches for the 6-year period or 14 percent of the total rainfall. The estimated evaporation of rainfall from that intercepted by crops plus that which wetted the soil was 52 percent. Except for November, the effective rainfall ranged from 40 to 50 percent for the period October through February. It decreased to 20 percent in March. The average annual effective rainfall was 34 percent of the total. Rainfall during the summer months is essentially non-effective because of small amounts and high evaporation rates.

REFERENCES

Gutwein, B.J., and R.J. Lang. 1993. Regional irrigation water demand. J. Irrig. and Drain. Engr. 119(5):829-847.

Haan, C.T., H.P. Johnson, and D.L. Brakensiek(eds). 1982. Hydrologic Modeling of Small Watersheds. ASAE Mono. 5, ASAE, St. Joseph, 543 pp.

Hanks, R.J., and J.T. Ritchie (eds). 1991. Modeling Plant and Soil Systems. Agron. Mono. 31, Am. Soc. Agron., Crop Sci. Soc. Am., and Soil Sci. Soc. Am., Madison, 561 pp.

Hershfield, D.M. 1964. Effective rainfall and irrigation water requirements. J. Irrig. and Drain. Div., ASCE 90(2):33-47.

Huggins, L.F. 1982. Surface runoff, storage and routing. Pp. 169-225. In: C.T. Haan, H.P. Johnson, and D.L. Brakensiek(eds). 1982. Hydrologic Modeling of Small Watersheds. ASAE Mono. 5, ASAE, St. Joseph, 543 pp.

Jensen, M.E., R.D. Burman, and R.G. Allen (eds). 1990. Evapotranspiration and Irrigation Water Requirements. ASCE Manuals and Reports on Engineering Practice No. 70, New York, 360 pp.

Kopec, A.R., M.N. Langley, and M.G. Bos. 1984. Major variables which influence effective precipitation. ICID Bull. 33(2):65-70, & 84.

Nieber, J.L., and A.S. Patwardhan. 1988. Estimation of effective rainfall. Research project completion report, Contract No. USDI-5-CR-81-07420, USDI, Bureau of Reclamation, Feb. Denver, Colo., 73 pp.

Patwardhan, A.S., J.L. Nieber, and E.L. Johns. 1990. Effective rainfall estimation methods. J. Irrig. and Drain. Engr. 116(2):182-193.

Soil Conservation Service. 1970. Technical Release 21. SCS, USDA, 92 pp.

Styles, S. 1993. On-Farm Irrigation Efficiency: Special Technical Report, Coachella Water District. April.

Williams, J.R. 1991. Runoff and water erosion. Pp. 439-455. In: R.J. Hanks, and J.T. Ritchie (eds). 1991. Modeling Plant and Soil Systems. Agron. Mono. 31, Am. Soc. Agron., Crop Sci. Soc. Am., and Soil Sci. Soc. Am., Madison, 561 pp.

APPENDIX A3-A

Effective Rainfall Calculations

Row 22-Feb-94 EFFECTIVE RAINFALL - THERMAL, CALIF \CVWD-ER

2 ==

3 B C D E F G H I J K L M N

4 INPUT DATA: For Day 1, assume Condition II (average condition)

5 For Day 2, assume Condition III (wet condition)

6 For Day 3, assume Condition III (wet condition)

7 Soil Type = "D", very slow infiltration, less than 0.05 in/h when wet.

8 Curve Number (CN):Condition II, row crops, average, = 89 Smx = 1.24 in

9 Condition I, row crops, soils dry = 78 Smx = 2.82 in

10 Condition III, row crops, soils wet= 96 Smx = 0.42 in

11 (Maximum retention, Smx = 1000/CN - 10)

12 Inter Calculation

13 Period: 1986-92 Storms, inches

Row	Year	Mo	Day 1	Day 2	Day 3	Day 4	Days from planting	Day 1 Int, in	Day 2 Int, in	Day 3 Int, in	Day1 Inter	Day2 Inter	Day2 Inter
16	1986	1	0.01				90	0.002	0.00	0.00	0.02	0.00	0.00
17	1986	1	0.08				90	0.02	0.00	0.00	0.09	0.00	0.00
18	1987	1	0.03				90	0.01	0.00	0.00	0.04	0.00	0.00
19	1988	1	0.44	0.52			90	0.09	0.10	0.00	0.17	0.17	0.00
20	1988	1	0.30				90	0.06	0.00	0.00	0.15	0.00	0.00
21	1989	1	0.09	0.59			90	0.02	0.12	0.00	0.09	0.18	0.00
22	1990	1					90	0.00	0.00	0.00	0.00	0.00	0.00
23	1991	1	0.26	0.07	0.01		90	0.05	0.01	0.00	0.15	0.08	0.02
24	1991	1	0.12				90	0.02	0.00	0.00	0.11	0.00	0.00
25	1992	1	0.18				90	0.04	0.00	0.00	0.13	0.00	0.00
26	1992	1	0.04				90	0.01	0.00	0.00	0.05	0.00	0.00
27	1986	2	0.52				120	0.10	0.00	0.00	0.23	0.00	0.00
28	1986	2	1.15				120	0.23	0.00	0.00	0.26	0.00	0.00
29	1987	2	0.16	0.09	0.02		120	0.03	0.02	0.00	0.16	0.12	0.04
30	1988	2	0.94				120	0.19	0.00	0.00	0.25	0.00	0.00
31	1989	2	0.01				120	0.00	0.00	0.00	0.02	0.00	0.00
32	1990	2	0.01				120	0.00	0.00	0.00	0.02	0.00	0.00
33	1991	2					120	0.00	0.00	0.00	0.00	0.00	0.00
34	1992	2	0.92	0.17			120	0.18	0.03	0.00	0.25	0.17	0.00
35	1992	2	0.82	0.14			120	0.16	0.03	0.00	0.25	0.15	0.00
36	1992	2	0.44				120	0.09	0.00	0.00	0.22	0.00	0.00
37	1986	3	0.19				150	0.04	0.00	0.00	0.22	0.00	0.00
38	1986	3	0.21				150	0.04	0.00	0.00	0.23	0.00	0.00
39	1987	3	0.18				150	0.04	0.00	0.00	0.21	0.00	0.00
40	1988	3	0.00				150	0.00	0.00	0.00	0.00	0.00	0.00
41	1989	3	0.03				150	0.01	0.00	0.00	0.07	0.00	0.00
42	1990	3	0.00				150	0.00	0.00	0.00	0.00	0.00	0.00
43	1991	3	0.57				150	0.11	0.00	0.00	0.29	0.00	0.00
44	1991	3	0.02	0.21			150	0.00	0.04	0.00	0.05	0.23	0.00
45	1991	3	0.21	0.46			150	0.04	0.09	0.00	0.23	0.28	0.00
46	1992	3	0.72				150	0.14	0.00	0.00	0.30	0.00	0.00
47	1992	3	0.08	0.04			150	0.02	0.01	0.00	0.14	0.09	0.00
48	1992	3	0.27	0.03			150	0.05	0.01	0.00	0.25	0.07	0.00
49	1992	3	0.49	0.03			150	0.10	0.01	0.00	0.29	0.07	0.00
50	1992	3	0.01	0.01			150	0.00	0.00	0.00	0.03	0.03	0.00
51	1986	4	0.01				180	0.00	0.00	0.00	0.03	0.00	0.00
52	1987	4	0.00				180	0.00	0.00	0.00	0.00	0.00	0.00
53	1988	4	0.17				180	0.03	0.00	0.00	0.25	0.00	0.00
54	1988	4	0.19				180	0.04	0.00	0.00	0.26	0.00	0.00

55	1989	4	0.00			180	0.00	0.00	0.00	0.00	0.00	0.00
56	1990	4	0.01			180	0.00	0.00	0.00	0.03	0.00	0.00
57	1991	4	0.00			180	0.00	0.00	0.00	0.00	0.00	0.00
58	1992	4	0.32			180	0.06	0.00	0.00	0.31	0.00	0.00
59	1986	5	0.00			210	0.00	0.00	0.00	0.00	0.00	0.00
60	1987	5	0.00			210	0.00	0.00	0.00	0.00	0.00	0.00
61	1988	5	0.00			210	0.00	0.00	0.00	0.00	0.00	0.00
62	1989	5	0.00			210	0.00	0.00	0.00	0.00	0.00	0.00
63	1990	5	0.02			210	0.00	0.00	0.00	0.07	0.00	0.00
64	1991	5	0.00			210	0.00	0.00	0.00	0.00	0.00	0.00
65	1992	5	0.12			210	0.02	0.00	0.00	0.25	0.00	0.00
66	1992	5	0.05			210	0.01	0.00	0.00	0.15	0.00	0.00
67	1986	6	0.00			240	0.00	0.00	0.00	0.00	0.00	0.00
68	1987	6	0.00			240	0.00	0.00	0.00	0.00	0.00	0.00
69	1988	6	0.00			240	0.00	0.00	0.00	0.00	0.00	0.00
70	1989	6	0.00			240	0.00	0.00	0.00	0.00	0.00	0.00
71	1990	6	0.09			240	0.02	0.00	0.00	0.25	0.00	0.00
72	1991	6	0.00			240	0.00	0.00	0.00	0.00	0.00	0.00
73	1992	6	0.00			240	0.00	0.00	0.00	0.00	0.00	0.00
74	1986	7	0.01									
75	1986	7	0.02									
76	1987	7	0.03									
77	1988	7	0.00									
78	1989	7	0.01									
79	1990	7	0.00									
80	1991	7	0.02									
81	1992	7	0.01									
82	1986	8	0.00									
83	1987	8	0.11									
84	1988	8	0.39									
85	1989	8										
86	1990	8	0.01	0.02								
87	1991	8	0.00									
88	1992	8	0.01									
89	1986	9	0.03									
90	1987	9	0.08									
91	1988	9	0.00									
92	1989	9	0.02									
93	1990	9	0.20									
94	1990	9	0.05									
95	1991	9	0.12	0.23								
96	1991	9	0.07	0.01								
97	1992	9	0.00									
98	1986	10	0.22	0.34		0	0.000	0.000	0.00	0.00	0.00	0.00
99	1987	10	0.38	0.34	0.05	0	0.000	0.000	0.00	0.00	0.00	0.00
100	1987	10	0.01			0	0.000	0.000	0.00	0.00	0.00	0.00
101	1987	10	0.01			0	0.000	0.000	0.00	0.00	0.00	0.00
102	1987	10	0.74			0	0.000	0.000	0.00	0.00	0.00	0.00
103	1988	10	0.00			0	0.000	0.000	0.00	0.00	0.00	0.00
104	1989	10				0	0.000	0.000	0.00	0.00	0.00	0.00
105	1990	10	0.02			0	0.000	0.000	0.00	0.00	0.00	0.00
106	1991	10	0.00			0	0.000	0.000	0.00	0.00	0.00	0.00
107	1992	10	0.31	0.19		0	0.000	0.000	0.00	0.00	0.00	0.00
108	1986	11	0.13			30	0.026	0.000	0.00	0.04	0.00	0.00

109	1987	11	0.34			30	0.053	0.000	0.00	0.05	0.00	0.00
110	1987	11	0.46	0.03		30	0.056	0.006	0.00	0.06	0.01	0.00
111	1987	11	0.09	0.02		30	0.018	0.004	0.00	0.03	0.01	0.00
112	1988	11	0.00			30	0.000	0.000	0.00	0.00	0.00	0.00
113	1989	11	0.00			30	0.000	0.000	0.00	0.00	0.00	0.00
114	1990	11	0.01			30	0.002	0.000	0.00	0.01	0.00	0.00
115	1991	11	0.03			30	0.006	0.000	0.00	0.01	0.00	0.00
116	1992	11	0.00			30	0.000	0.000	0.00	0.00	0.00	0.00
117	1986	12	0.05	0.02		60	0.010	0.004	0.00	0.04	0.02	0.00
118	1987	12	0.08			60	0.016	0.000	0.00	0.06	0.00	0.00
119	1987	12	0.54	0.01	0.02	60	0.108	0.002	0.00	0.12	0.01	0.02
120	1988	12	0.01			60	0.002	0.000	0.00	0.01	0.00	0.00
121	1988	12	0.01			60	0.002	0.000	0.00	0.01	0.00	0.00
122	1989	12				60	0.000	0.000	0.00	0.00	0.00	0.00
123	1990	12	0.00			60	0.000	0.000	0.00	0.00	0.00	0.00
124	1991	12	0.27	0.01	0.42	60	0.054	0.002	0.08	0.10	0.01	0.11
125	1991	12	0.19			60	0.038	0.000	0.00	0.09	0.00	0.00
126	1991	12	0.07			60	0.014	0.000	0.00	0.05	0.00	0.00
127	1992	12	0.15	0.29		60	0.030	0.058	0.00	0.08	0.10	0.00
128	1992	12	0.19			60	0.038	0.000	0.00	0.09	0.00	0.00
129	1992	12	0.32	0.04		60	0.064	0.008	0.00	0.10	0.04	0.00

130 ---

131		16.30	3.91	0.52	0.00	20.73	
132			Storms, inches				
133		Day 1	Day 2	Day 3	Day 4	Total	
134	Runoff =	1.65	1.02	0.15	0.00	2.81	13.6%
135	Incr Evap =					10.83	52.2%
136	No. of storms	109	25	5	0		
137							
138	Total losses					13.64	65.8%
139	Effective rainfall					7.09	34.2%
140							

141	MONTHLY SUMMARY:	D,E,F,G	P,R,T	AA					
142		Rain	Runoff	E+	RO + E+	ER, in.	ER, %		
143	R16-26	Jan	2.74	0.53	1.11	1.63	1.11	40%	40.4
144	R27-36	Feb	5.39	1.15	1.83	2.97	2.42	45%	44.8
145	R37-50	Mar	3.76	0.45	2.55	3.00	0.76	20%	20.2
146	R51-58	Apr	0.70	0.00	0.70	0.70	0.00	0%	0.0
147	R59-66	May	0.19	0.00	0.19	0.19	0.00	0%	0.0
148	R67-73	Jun	0.09	0.00	0.09	0.09	0.00	0%	0.0
149	R74-81	Jul	0.10	0.00	0.10	0.10	0.00	0%	0.0
150	R82-88	Aug	0.54	0.00	0.54	0.54	0.00	0%	0.0
151	R89-97	Sep	0.81	0.00	0.81	0.81	0.00	0%	0.0
152	R98-107	Oct	2.61	0.37	1.13	1.50	1.11	43%	42.6
153	R108-116	Nov	1.11	0.04	0.69	0.73	0.38	34%	34.1
154	R117-129	Dec	2.69	0.28	1.10	1.38	1.31	49%	48.9
155			-----	-----	-----	-----	-----	-----	
156	Annual		20.73	2.81	10.83	13.64	7.09	34%	
157	Percent		100%	14%	52%	66%	34%		

22-Feb-94 EFFECTIVE RAINFALL - THERMAL, CALIF \CVWD-ER Row

== 2

O	P	Q	R	S	T	U	V	W	X	Y	Z	AA		3
					Page 118, ASCE Man. 70:			Incr E = 0.35[1.5 + Td][(K1 - Kc) ETo]						4
								Td = 7 days for clay loams soils						5
								Pot E+ = 0.35[8.5][(K1 - Kc)ETo]						6
								Limit = E+ (P - RO)/(0.35(8.5)(K1 - Kc)ETo)						7
								K1 = 1.2						8
		Runoff calculations						Non-beneficial evaporation calculations						9
														10
Day 1		Day 2		Day 3					Increased evaporation after rains					11
														12
Run off,	inches	Run off,	inches	Run off,	inches	ETo	Avg	ET	P - RO	Pot E+	Limit	Actual		13
Threshold	Amount	Threshold	Amount	Threshold	Amount	In/d	Kc	in.	In.	In.	In.	E+	Mo	14
														15
0.247	0	0.083	0	0.083	0	0.079	0.50	0.040	0.010	0.165	0.010	0.010	1	16
0.247	0	0.083	0	0.083	0	0.079	0.50	0.040	0.080	0.165	0.080	0.080	1	17
0.247	0	0.083	0	0.083	0	0.079	0.50	0.040	0.030	0.165	0.030	0.030	1	18
0.247	0.026	0.083	0.223	0.083	0	0.079	0.50	0.040	0.711	0.165	0.711	0.165	1	19
0.247	0	0.083	0	0.083	0	0.079	0.50	0.040	0.300	0.165	0.300	0.165	1	20
0.247	0	0.083	0.278	0.083	0	0.079	0.50	0.040	0.402	0.165	0.402	0.165	1	21
0.247	0	0.083	0	0.083	0	0.079	0.50	0.040	0.000	0.165	0.000	0.000	1	22
0.247	0	0.083	0	0.083	0	0.079	0.50	0.040	0.340	0.165	0.340	0.165	1	23
0.247	0	0.083	0	0.083	0	0.079	0.50	0.040	0.120	0.165	0.120	0.120	1	24
0.247	0	0.083	0	0.083	0	0.079	0.50	0.040	0.180	0.165	0.180	0.165	1	25
0.247	0	0.083	0	0.083	0	0.079	0.50	0.040	0.040	0.165	0.040	0.040	1	26
0.247	0.049	0.083	0	0.083	0	0.136	0.56	0.076	0.471	0.258	0.471	0.258	2	27
0.247	0.381	0.083	0	0.083	0	0.136	0.56	0.076	0.769	0.258	0.769	0.258	2	28
0.247	0	0.083	0	0.083	0	0.136	0.56	0.076	0.270	0.258	0.270	0.258	2	29
0.247	0.249	0.083	0	0.083	0	0.136	0.56	0.076	0.691	0.258	0.691	0.258	2	30
0.247	0	0.083	0	0.083	0	0.136	0.56	0.076	0.010	0.258	0.010	0.010	2	31
0.247	0	0.083	0	0.083	0	0.136	0.56	0.076	0.010	0.258	0.010	0.010	2	32
0.247	0	0.083	0	0.083	0	0.136	0.56	0.076	0.000	0.258	0.000	0.000	2	33
0.247	0.237	0.083	0.015	0.083	0	0.136	0.56	0.076	0.838	0.258	0.838	0.258	2	34
0.247	0.181	0.083	0.007	0.083	0	0.136	0.56	0.076	0.772	0.258	0.772	0.258	2	35
0.247	0.026	0.083	0.000	0.083	0	0.136	0.56	0.076	0.414	0.258	0.414	0.258	2	36
0.247	0	0.083	0	0.083	0	0.189	0.62	0.117	0.190	0.326	0.190	0.190	3	37
0.247	0	0.083	0	0.083	0	0.189	0.62	0.117	0.210	0.326	0.210	0.210	3	38
0.247	0	0.083	0	0.083	0	0.189	0.62	0.117	0.180	0.326	0.180	0.180	3	39
0.247	0	0.083	0	0.083	0	0.189	0.62	0.117	0.000	0.326	0.000	0.000	3	40
0.247	0	0.083	0	0.083	0	0.189	0.62	0.117	0.030	0.326	0.030	0.030	3	41
0.247	0	0.083	0	0.083	0	0.189	0.62	0.117	0.000	0.326	0.000	0.000	3	42
0.247	0.067	0.083	0	0.083	0	0.189	0.62	0.117	0.503	0.326	0.503	0.326	3	43
0.247	0	0.083	0.030	0.083	0	0.189	0.62	0.117	0.200	0.326	0.200	0.200	3	44
0.247	0	0.083	0.179	0.083	0	0.189	0.62	0.117	0.491	0.326	0.491	0.326	3	45
0.247	0.131	0.083	0	0.083	0	0.189	0.62	0.117	0.589	0.326	0.589	0.326	3	46
0.247	0	0.083	0	0.083	0	0.189	0.62	0.117	0.120	0.326	0.120	0.120	3	47
0.247	0	0.083	0	0.083	0	0.189	0.62	0.117	0.300	0.326	0.300	0.300	3	48
0.247	0.040	0.083	0	0.083	0	0.189	0.62	0.117	0.480	0.326	0.480	0.326	3	49
0.247	0	0.083	0	0.083	0	0.189	0.62	0.117	0.020	0.326	0.020	0.020	3	50
0.247	0	0.083	0	0.083	0	0.246	0.62	0.153	0.010	0.425	0.010	0.010	4	51
0.247	0	0.083	0	0.083	0	0.246	0.62	0.153	0.000	0.425	0.000	0.000	4	52
0.247	0	0.083	0	0.083	0	0.246	0.62	0.153	0.170	0.425	0.170	0.170	4	53
0.247	0	0.083	0	0.083	0	0.246	0.62	0.153	0.190	0.425	0.190	0.190	4	54

0.247	0	0.083	0	0.083	0	0.246	0.62	0.153	0.000	0.425	0.000	0.000	4	55
0.247	0	0.083	0	0.083	0	0.246	0.62	0.153	0.010	0.425	0.010	0.010	4	56
0.247	0	0.083	0	0.083	0	0.246	0.62	0.153	0.000	0.425	0.000	0.000	4	57
0.247	0.004	0.083	0	0.083	0	0.246	0.62	0.153	0.316	0.425	0.316	0.316	4	58
0.247	0	0.083	0	0.083	0	0.298	0.6	0.179	0.000	0.532	0.000	0.000	5	59
0.247	0	0.083	0	0.083	0	0.298	0.6	0.179	0.000	0.532	0.000	0.000	5	60
0.247	0	0.083	0	0.083	0	0.298	0.6	0.179	0.000	0.532	0.000	0.000	5	61
0.247	0	0.083	0	0.083	0	0.298	0.6	0.179	0.000	0.532	0.000	0.000	5	62
0.247	0	0.083	0	0.083	0	0.298	0.6	0.179	0.020	0.532	0.020	0.020	5	63
0.247	0	0.083	0	0.083	0	0.298	0.6	0.179	0.000	0.532	0.000	0.000	5	64
0.247	0	0.083	0	0.083	0	0.298	0.6	0.179	0.120	0.532	0.120	0.120	5	65
0.247	0	0.083	0	0.083	0	0.298	0.6	0.179	0.050	0.532	0.050	0.050	5	66
0.247	0	0.083	0	0.083	0	0.322	0.5	0.161	0.000	0.671	0.000	0.000	6	67
0.247	0	0.083	0	0.083	0	0.322	0.5	0.161	0.000	0.671	0.000	0.000	6	68
0.247	0	0.083	0	0.083	0	0.322	0.5	0.161	0.000	0.671	0.000	0.000	6	69
0.247	0	0.083	0	0.083	0	0.322	0.5	0.161	0.000	0.671	0.000	0.000	6	70
0.247	0	0.083	0	0.083	0	0.322	0.5	0.161	0.090	0.671	0.090	0.090	6	71
0.247	0	0.083	0	0.083	0	0.322	0.5	0.161	0.000	0.671	0.000	0.000	6	72
0.247	0	0.083	0	0.083	0	0.322	0.5	0.161	0.000	0.671	0.000	0.000	6	73
						0.295	0.5	0.148	0.010	0.615	0.010	0.010	7	74
						0.295	0.5	0.148	0.020	0.615	0.020	0.020	7	75
						0.295	0.5	0.148	0.030	0.615	0.030	0.030	7	76
						0.295	0.5	0.148	0.000	0.615	0.000	0.000	7	77
						0.295	0.5	0.148	0.010	0.615	0.010	0.010	7	78
						0.295	0.5	0.148	0.000	0.615	0.000	0.000	7	79
						0.295	0.5	0.148	0.020	0.615	0.020	0.020	7	80
						0.295	0.5	0.148	0.010	0.615	0.010	0.010	7	81
						0.265	0.3	0.079	0.000	0.708	0.000	0.000	8	82
						0.265	0.3	0.079	0.110	0.708	0.110	0.110	8	83
						0.265	0.3	0.079	0.390	0.708	0.390	0.390	8	84
						0.265	0.3	0.079	0.000	0.708	0.000	0.000	8	85
						0.265	0.3	0.079	0.030	0.708	0.030	0.030	8	86
						0.265	0.3	0.079	0.000	0.708	0.000	0.000	8	87
						0.265	0.3	0.079	0.010	0.708	0.010	0.010	8	88
						0.238	0.62	0.148	0.030	0.411	0.030	0.030	9	89
						0.238	0.62	0.148	0.080	0.411	0.080	0.080	9	90
						0.238	0.62	0.148	0.000	0.411	0.000	0.000	9	91
						0.238	0.62	0.148	0.020	0.411	0.020	0.020	9	92
						0.238	0.62	0.148	0.200	0.411	0.200	0.200	9	93
						0.238	0.62	0.148	0.050	0.411	0.050	0.050	9	94
						0.238	0.62	0.148	0.350	0.411	0.350	0.350	9	95
						0.238	0.62	0.148	0.080	0.411	0.080	0.080	9	96
						0.238	0.62	0.148	0.000	0.411	0.000	0.000	9	97
0.247	0	0.083	0.098	0.083	0	0.160	0.63	0.101	0.462	0.271	0.462	0.271	10	98
0.247	0.013	0.083	0.098	0.083	0	0.160	0.63	0.101	0.659	0.271	0.659	0.271	10	99
0.247	0	0.083	0	0.083	0	0.160	0.63	0.101	0.010	0.271	0.010	0.010	10	100
0.247	0	0.083	0	0.083	0	0.160	0.63	0.101	0.010	0.271	0.010	0.010	10	101
0.247	0.140	0.083	0	0.083	0	0.160	0.63	0.101	0.600	0.271	0.600	0.271	10	102
0.247	0	0.083	0	0.083	0	0.160	0.63	0.101	0.000	0.271	0.000	0.000	10	103
0.247	0	0.083	0	0.083	0	0.160	0.63	0.101	0.000	0.271	0.000	0.000	10	104
0.247	0	0.083	0	0.083	0	0.160	0.63	0.101	0.020	0.271	0.020	0.020	10	105
0.247	0	0.083	0	0.083	0	0.160	0.63	0.101	0.000	0.271	0.000	0.000	10	106
0.247	0.003	0.083	0.022	0.083	0	0.160	0.63	0.101	0.475	0.271	0.475	0.271	10	107
0.247	0	0.083	0	0.083	0	0.101	0.51	0.051	0.130	0.207	0.130	0.130	11	108

APPENDIX A3-A

0.247	0.006	0.083	0	0.083	0	0.101	0.51	0.051	0.334	0.207	0.334	0.207	11
0.247	0.031	0.083	0	0.083	0	0.101	0.51	0.051	0.459	0.207	0.459	0.207	11
0.247	0	0.083	0	0.083	0	0.101	0.51	0.051	0.110	0.207	0.110	0.110	11
0.247	0	0.083	0	0.083	0	0.101	0.51	0.051	0.000	0.207	0.000	0.000	11
0.247	0	0.083	0	0.083	0	0.101	0.51	0.051	0.000	0.207	0.000	0.000	11
0.247	0	0.083	0	0.083	0	0.101	0.51	0.051	0.010	0.207	0.010	0.010	11
0.247	0	0.083	0	0.083	0	0.101	0.51	0.051	0.030	0.207	0.030	0.030	11
0.247	0	0.083	0	0.083	0	0.101	0.51	0.051	0.000	0.207	0.000	0.000	11
0.247	0	0.083	0	0.083	0	0.072	0.53	0.038	0.070	0.143	0.070	0.070	12
0.247	0	0.083	0	0.083	0	0.072	0.53	0.038	0.080	0.143	0.080	0.080	12
0.247	0.056	0.083	0	0.083	0	0.072	0.53	0.038	0.514	0.143	0.514	0.143	12
0.247	0	0.083	0	0.083	0	0.072	0.53	0.038	0.010	0.143	0.010	0.010	12
0.247	0	0.083	0	0.083	0	0.072	0.53	0.038	0.010	0.143	0.010	0.010	12
0.247	0	0.083	0	0.083	0	0.072	0.53	0.038	0.000	0.143	0.000	0.000	12
0.247	0	0.083	0	0.083	0	0.072	0.53	0.038	0.000	0.143	0.000	0.000	12
0.247	0	0.083	0	0.083	0.150	0.072	0.53	0.038	0.550	0.143	0.550	0.143	12
0.247	0	0.083	0	0.083	0	0.072	0.53	0.038	0.190	0.143	0.190	0.143	12
0.247	0	0.083	0	0.083	0	0.072	0.53	0.038	0.070	0.143	0.070	0.070	12
0.247	0	0.083	0.069	0.083	0	0.072	0.53	0.038	0.371	0.143	0.371	0.143	12
0.247	0	0.083	0	0.083	0	0.072	0.53	0.038	0.190	0.143	0.190	0.143	12
0.247	0.004	0.083	0	0.083	0	0.072	0.53	0.038	0.356	0.143	0.356	0.143	12
	1.65		1.02		0.15							10.83	

APPENDIX 4

EVALUATING REFERENCE EVAPOTRANSPIRATION ESTIMATES FOR IID

APPENDIX 4

EVALUATING REFERENCE EVAPOTRANSPIRATION ESTIMATES FOR IID

by
Marvin E. Jensen
12 Oct 93

INTRODUCTION

During the Technical Work Group (TWG) discussions on 15 September 1993, we discussed the 20 percent decrease in estimated grass reference evapotranspiration (ET_0) from 1987 to 1992 (from 82.8 inches to 65.8 inches). Such a large magnitude of change is very unusual for an arid environment where the main diving force (solar radiation) is expected to remain relatively constant during the 6-year period. Although CIMIS ET_0 values can be used directly for estimating evaporative demand and crop ET, accurate climatological data are needed for confirming ET values and estimating crop ET where crop coefficients are related to climate, or crop growth models require weather data input. Likewise, estimates of evaporation from water surfaces require either a modified Penman-Monteith equation or a calibration of evaporation v. ET_0. These estimates are needed to provide alternative estimates of on-farm irrigation efficiencies.

Disk file copies (UPDATE.DBF and UPDATE1.DBF) of CIMIS data used in preparing the summary data in the Boyle/Styles (1993) report were provided by Charles Burt. UPDATE1.DBF contains data for only the three CIMIS sites 41 (Mulberry), 68 (Seeley) and 87 (Meloland). The purpose of reviewing CIMIS evaporation (ET_0) and weather data was to evaluate possible changes in the sensors, particularly the solar radiation sensor, during the 6-year period that may have caused part of the large decrease in evaporative demand.

PROBABLE CAUSES OF ERRORS IN THE DATA

Mean monthly CIMIS solar radiation values from the CIMIS Station 41 (Mulberry) file were first compared with values shown on pages A-52 and A-53 from the Boyle/Styles report (Styles, 1993). Significant differences were found beginning in September 1987. Differences became more frequent from 1990 through 1992. Therefore, in order to evaluate ET_0 estimates using mean monthly data, it was first necessary to evaluate the accuracy of all of the mean monthly values shown in the tables for the three sites for which an analysis was desired (CIMIS Station 41, Mulberry; CIMIS Station 68, Seeley; and CIMIS Station 87, Meloland).

The CIMIS data file contains values with various flags noted on some data. I contacted and obtained a listing of the flags used in CIMIS from Rick Snyder, University of California/Davis.

However, some of the flags in the data file were not the same as those in the original CIMIS files.

For CIMIS Station 41, it soon became apparent that the solar radiation values shown on pages A-52 to A-53 were averages for each month using **all of the data**. However, whenever there apparently was an instrument problem, a **"zero"** appeared in the daily data with a "C" flag. Other flags in the solar radiation data were H and Y. The H-flag was used when one or more hourly values was severe. The Y-flag was not explained for solar radiation, but for other variables it is used when the value is outside of a specific range. Thus, it became apparent that an independent evaluation of mean monthly ET_0 estimates could not be made without first evaluating all of the mean monthly input data. Since the mean monthly values contained averaging errors, the values obtained with Pruitt's spreadsheet program cannot be compared directly either CIMIS ET_0 values or my estimates of ET_0.

PROCEDURES

Evaluating Mean Monthly Weather Data

Daily data for each of the three CIMIS stations (CIMIS-41, CIMIS-68, and CIMIS 87) corresponding to the sites used in the Boyle/Styles report were used. Data for each of the main weather variables, solar radiation, maximum and minimum air temperatures, dewpoint temperature and wind run in the UPDATE1.DBF file were first exported to a WK1 file for each of the three stations. Mean monthly values of the variables of interest were then obtained by "excluding" all daily values that were **zero**. In the case of dewpoint, there were also some large negative values with an "L" flag which were also excluded. Values with other flags were included if they appeared reasonable.

Estimating Reference ET

After cleaning up the data from the UPDATE1.DBF file, a spreadsheet program was set up to estimate mean monthly reference evapotranspiration values using the Penman (1963) and Penman-Monteith (P-M) method (Smith, 1991). The same estimate of net radiation was used with both methods. Therefore, the main differences between these two methods were the procedures used to estimate vapor pressure deficit, the aerodynamic component and the weighting of the radiation and aerodynamic terms of the combination equation. The equations used are summarized in Appendix A. The two methods are explained in ASCE Manual 70 Jensen et al., 1990) with recent modifications of the P-M method summarized by Smith (1991).

Vapor Pressure Deficit. The calculated vapor pressure deficit used in the Penman (1963) method was based on the difference between the saturation vapor pressure at **mean air temperature** and saturation vapor pressure at **dewpoint temperature**. The P-M method uses the difference between mean of the saturation vapor pressure at **maximum and minimum air temperatures** and saturation vapor pressure at **dewpoint temperature**.

Wind Function. The Penman (1963) method uses a linear wind function $W_f = 1.0 + 0.536$ u2 where u2 the mean wind speed at a height of 2 meters in m/s, or $W_f = 1.0 + 0.01$ u2 where u2 is the daily wind run at a height of 2 meters in miles per day. The P-M method uses an aerodynamic wind function that is related to the heights of temperature, humidity and wind speed measurements, the height of the reference crop and its leaf-area-index, canopy resistance and surface roughness. Therefore, P-M estimates can be adjusted for specific weather instruments and site conditions.

Relative Cloud Cover or Percent of Possible Sunshine

Cloud cover or percent of possible sunshine is not a CIMIS variable, but is needed in estimating net radiation. Daily **extraterrestrial solar radiation** (R_a) was first calculated for latitude 33 degrees N using equations from the Insolation Data Manual (Solar Energy Research Institute, 1980). A solar constant of 0.082 megajoules per square meter per minute (MJ/(m^2 min) or 1.96 langleys per minute was used.

The ratio of **clear day solar radiation** (R_{so}) to extraterrestrial solar radiation, R_{so}/R_a, varies during the year because of changes in the declination of the sun. A functional relationship between R_{so} and R_a was developed by selecting high daily values of solar radiation near the middle of each month from the CIMIS data sets and relating these to R_a. The resulting equation for IID is given in Appendix A.

Mean Daily Albedo

Mean daily albedo also changes with solar declination or zenith angle. Hourly albedo values have been developed as a function of latitude (Dong et al., 1992). However, a mean daily functional relationship between albedo and latitude remains to be developed. Therefore, I modified the albedo function developed by Wright (ASCE Manual p. 137) to obtain a functional relationship applicable throughout the year. The resulting equation is in Appendix A.

POSSIBLE CAUSES LARGE DECREASES IN ANNUAL REFERENCE ET

Major Variables

Solar radiation is the main energy input affecting the evaporative demand during the year. If sensor calibrations drifted over the six-year period, then a calculated decrease in reference ET might be caused partly by instrument error. The other two main variables affecting estimated reference ET are humidity, as indicated by **dewpoint**, and **wind speed** as indicated by total daily wind run.

Indirect Rainfall Effects

A significant increase in annual rainfall occurred during the last two years of the six-year period as shown in Table 1. Very low rainfall in 1989 could be expected to slightly increase mean annual solar radiation with a corresponding decrease in mean annual humidity (dewpoint). Similarly, the unusually high rainfall in 1991, and especially in 1992, would have opposite effects lowering the evaporative demand in 1991 and 1992.

Table 1. Summary of rainfall recorded at CIMIS Stations 41, 68 and 87.

Year	Station 41		Station 68		Station 87		Average
	Inches	Percent	Inches	Percent	Inches	Percent	Inches
1987	3.51	82	--	--	--	--	3.51
1988	3.30	77	3.10	75	--	--	3.20
1989	2.11	49	2.86	69	--	--	2.49
1990	2.36	55	1.52	37	2.95	66	2.28
1991	6.34	147	5.94	144	3.31	74	5.20
1992	8.19	190	7.27	176	7.24	161	7.57
Average	4.30	100	4.14	100	4.50	100	4.04
Avg., 90-92	5.63	131	4.91	119	4.50	100	5.01
Percent of 1987-1992 average							124%

Most of the rainfall occurs during the October-March period. The annual rainfall during the six-year period for the three CIMIS sites is shown in Figure 1. The relative effects of increased rainfall and associated cloudiness on solar radiation, dewpoint temperature and wind speed for the CIMIS 41 station is shown in Figure 2. Mean annual solar radiation remained fairly constant from 1987 through 1990, but decreased significantly in 1991 and 1992. Likewise, mean wind speed decreased greatly in 1991 and 1992. Mean annual dewpoint temperature increased in 1991 and 1992. The climatic conditions in 1991 and 1992 would decrease estimated reference ET from the long-term average. Clearly, rainfall, though very limited, has significant effects on the variables affecting the evaporative demand in the Imperial Irrigation District.

RESULTS OF ANALYSES

Corrected Mean Climate Data

The mean monthly data for CIMIS Station 41 shown on pages A-52 and A-53 of the Boyle/Styles report are generally low starting in 1988 when instrument problems apparently resulted in "zeros" in the CIMIS data file. The relative magnitudes of these effects for Station 41 are illustrated in Fig. 3. Most of the mean monthly climatic variables were 4 to 6 percent low. Smaller effects existed for CIMIS Station 68 and especially Station 87 with only three years of data. Apparently, these stations were newer and had fewer instrument problems.

A summary of the data from the data file UPDATE1.DBF relative to that reported on pages A-52 to A-53 for Station 41 and on page A-49 for Station 87 is presented in Appendix B. Values for Station 68 were not available in the Styles report for comparison although they could have been generated by including all values in calculated monthly means.

Decreasing Annual Reference ET

After correcting mean monthly climate data, the estimates of annual ET for CIMIS Stations 41, 68 and 87 using the Penman-Monteith and Penman (1963) equations showed a general downward trend similar to that obtained from the CIMIS ET_o data are illustrated in Figures 4-6.

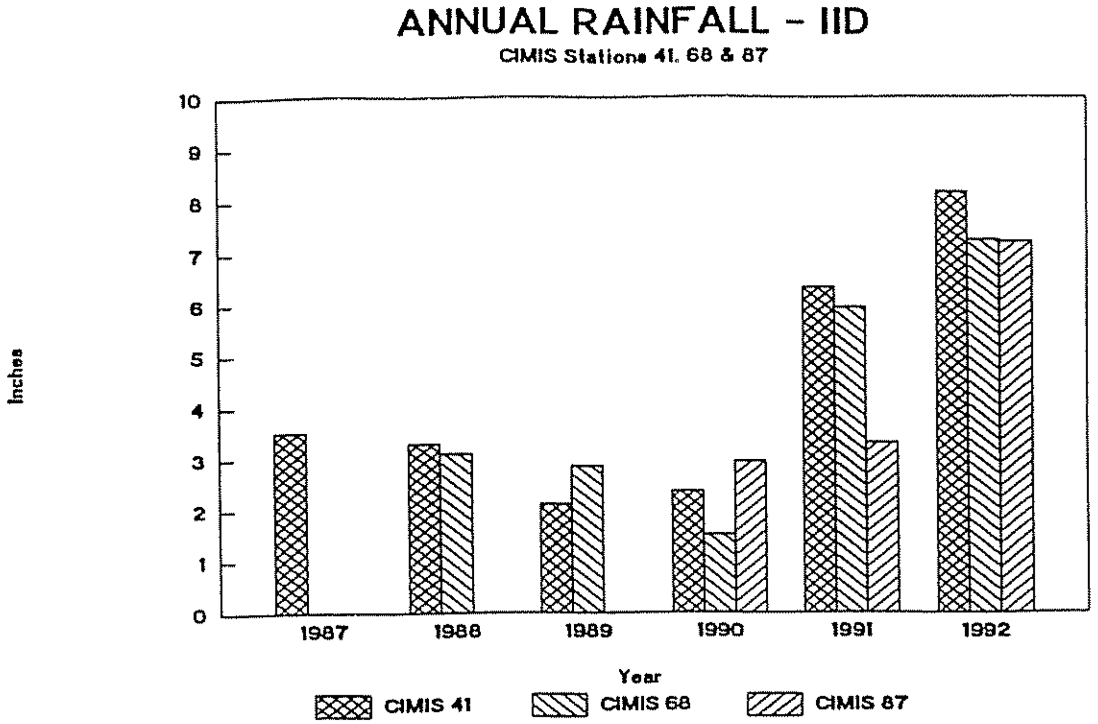


Figure 1. Annual rainfall for CIMIS Station 41 (Mulberry), Station 68 (Seeley), and Station 87 (Meloland) from 1987 to 1992.

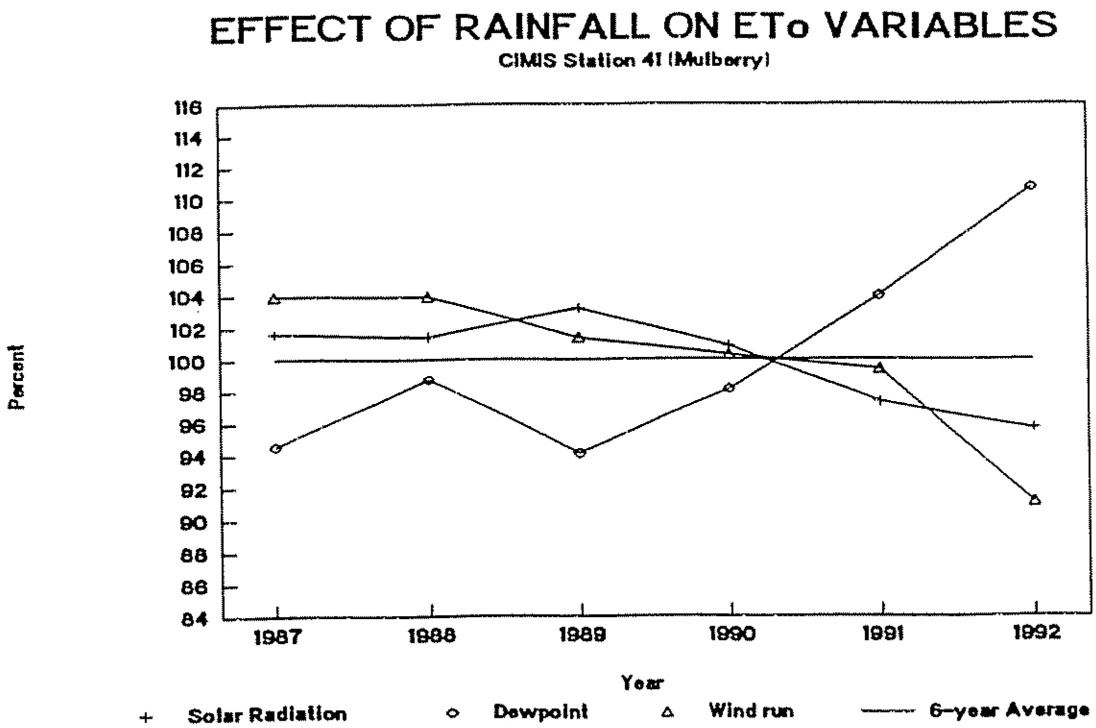


Figure 2. Relative Effects of rainfall on climatic variables that determine estimated reference ET.

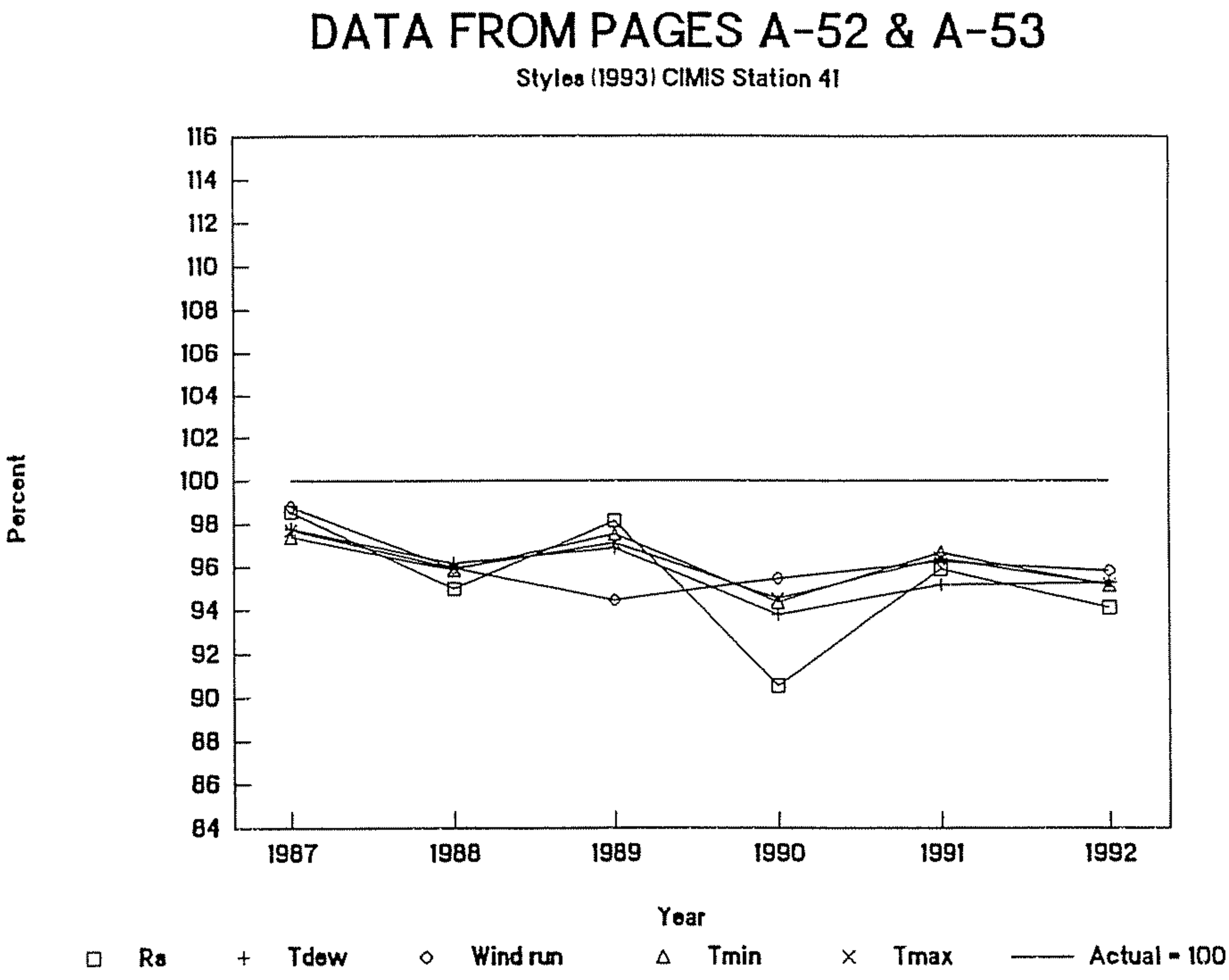


Figure 3. Relative effects of including "zeros" when computing 1987-1992 mean monthly climatic data for CIMIS Station 41 (Mulberry) reported on pages A-52 and A-53 of the Boyle/Styles report (Styles, 1993).

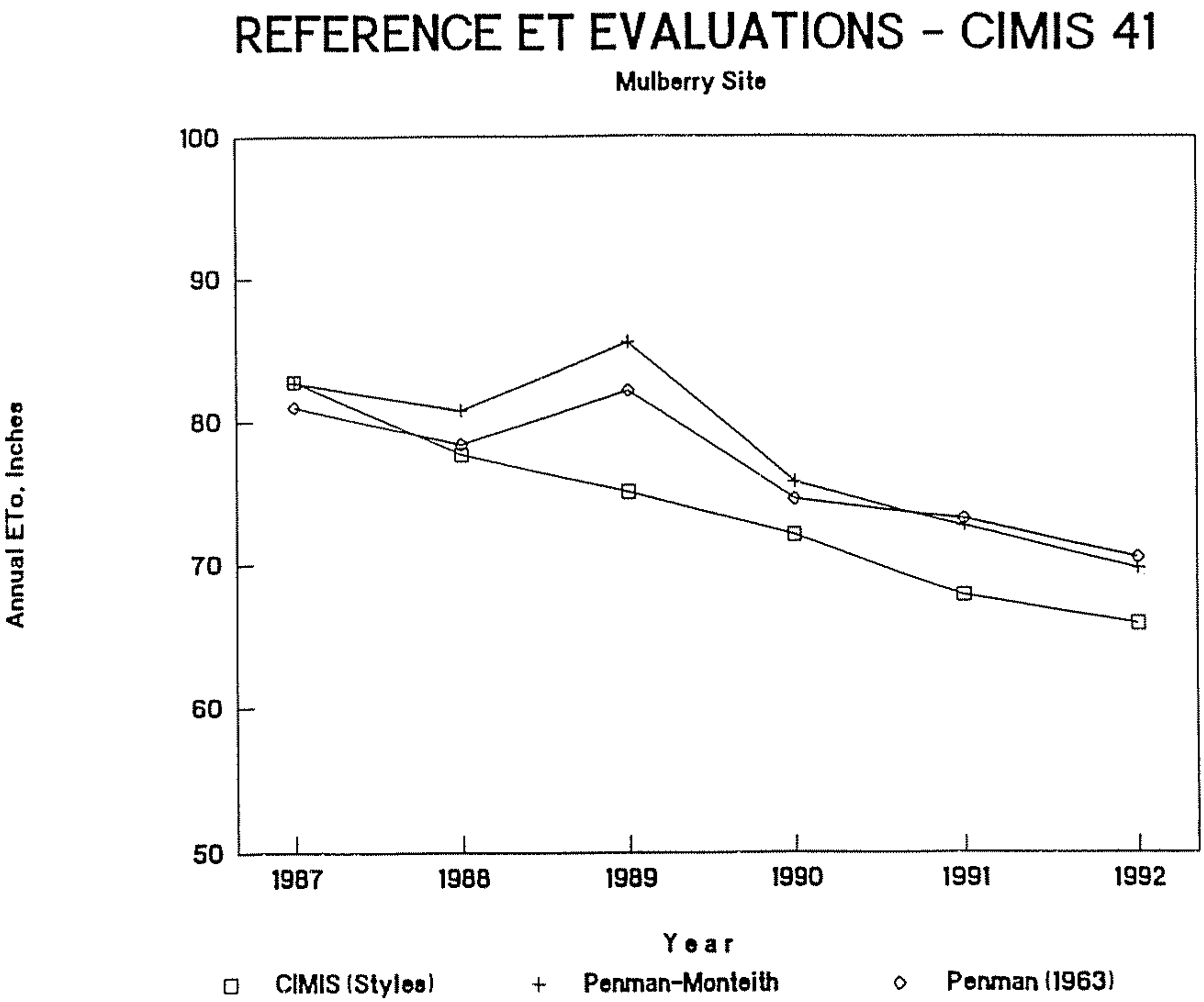


Figure 4. Comparison of annual reference ET for CIMIS Station 41 (Mulberry), computed with the Penman-Monteith and Penman (1963) equations with CIMIS values.

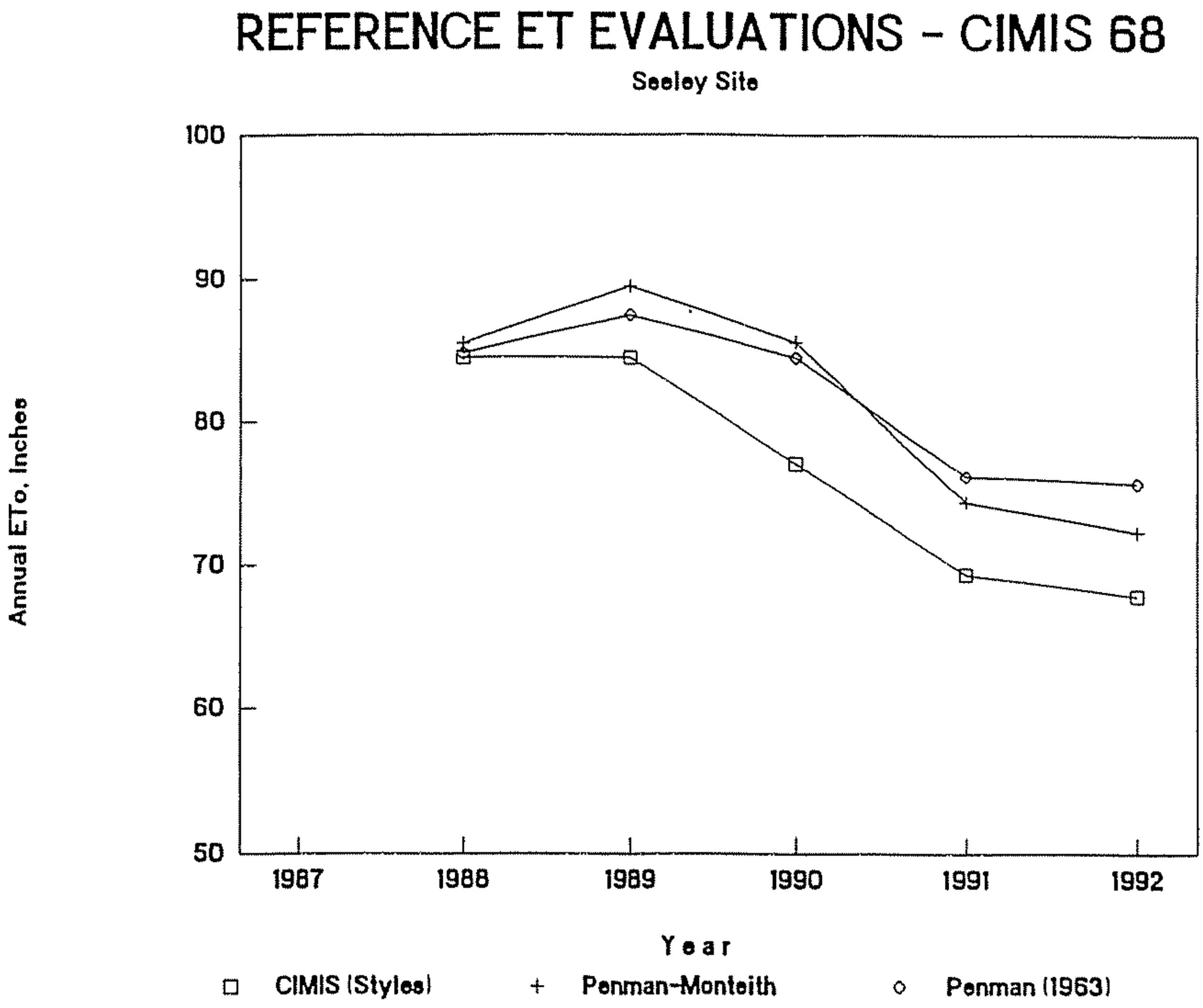


Figure 5. Comparison of annual reference ET for CIMIS Station 68 (Seeley) computed with the Penman-Monteith and Penman (1963) equations with CIMIS values.

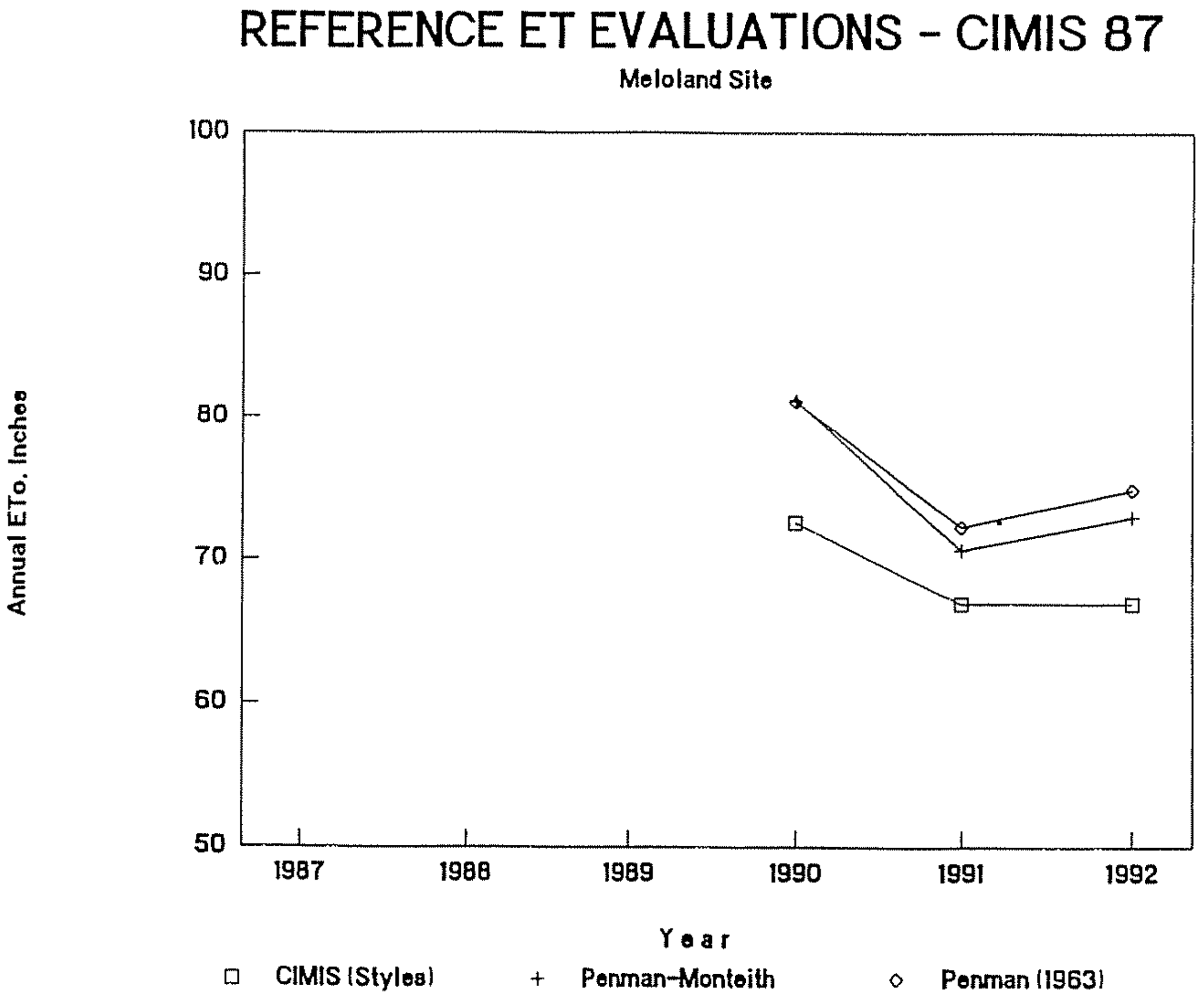


Figure 6. Comparison of annual reference ET for CIMIS Station 87 (Meloland) computed with the Penman-Monteith and Penman (1963) equations with CIMIS values.

Monthly Reference ET

Comparisons of estimated mean monthly reference ET values using the P-M and Penman (1963) equations with CIMIS values are shown in Figures 7-9 for the period 1990-1992. The three-year period, 1990-1992, is used because data from all three sites were available for this period. Clearly, the estimates using the combination equations and my procedures exceed CIMIS values from May through October. The estimates were made using average monthly data while the CIMIS values are averages of daily values which in turn are based on hourly totals.

The main effect of the differences in mean monthly estimates appear to reflect the lag in temperature from solar radiation. The largest differences occurred at CIMIS Station 68 (Meloland) as shown in Fig. 9. This site currently is in alfalfa which would have higher humidity and lower wind speeds at instrument height than at grass sites. A first adjustment in the P-M method would be to change the crop height and aerodynamic roughness over which the measurements are made relative to the other two sites.

Differences Between CIMIS and P-M Values

A comparison of mean monthly reference ET estimates using the P-M equation and mean monthly climatic data averaged for the three stations with CIMIS values is shown in Fig. 10. The Penman-Monteith and Penman (1963) equations used with mean monthly climatic data were consistently about 8 to 9 percent higher than the CIMIS values. It would be fairly simple to modify the P-M equation for mean monthly estimates using mean monthly weather input data to more closely match the CIMIS values at each site. The first general adjustments might be to use the vapor pressure deficit based on mean air temperature, or to increase the canopy resistance for the reference crop. A summary of annual values is shown in Appendix A.

Differences Between CIMIS Sites

A comparison of differences between CIMIS sites is shown in Fig. 11 using the CIMIS data and in Fig. 12 using the P-M equation. Clearly, the reference ET values at CIMIS site 68 is higher from March through June than at the other two sites. Site 68, Seeley, is on the west side of the valley and the higher early season values probably reflect the drier air flow from the west.

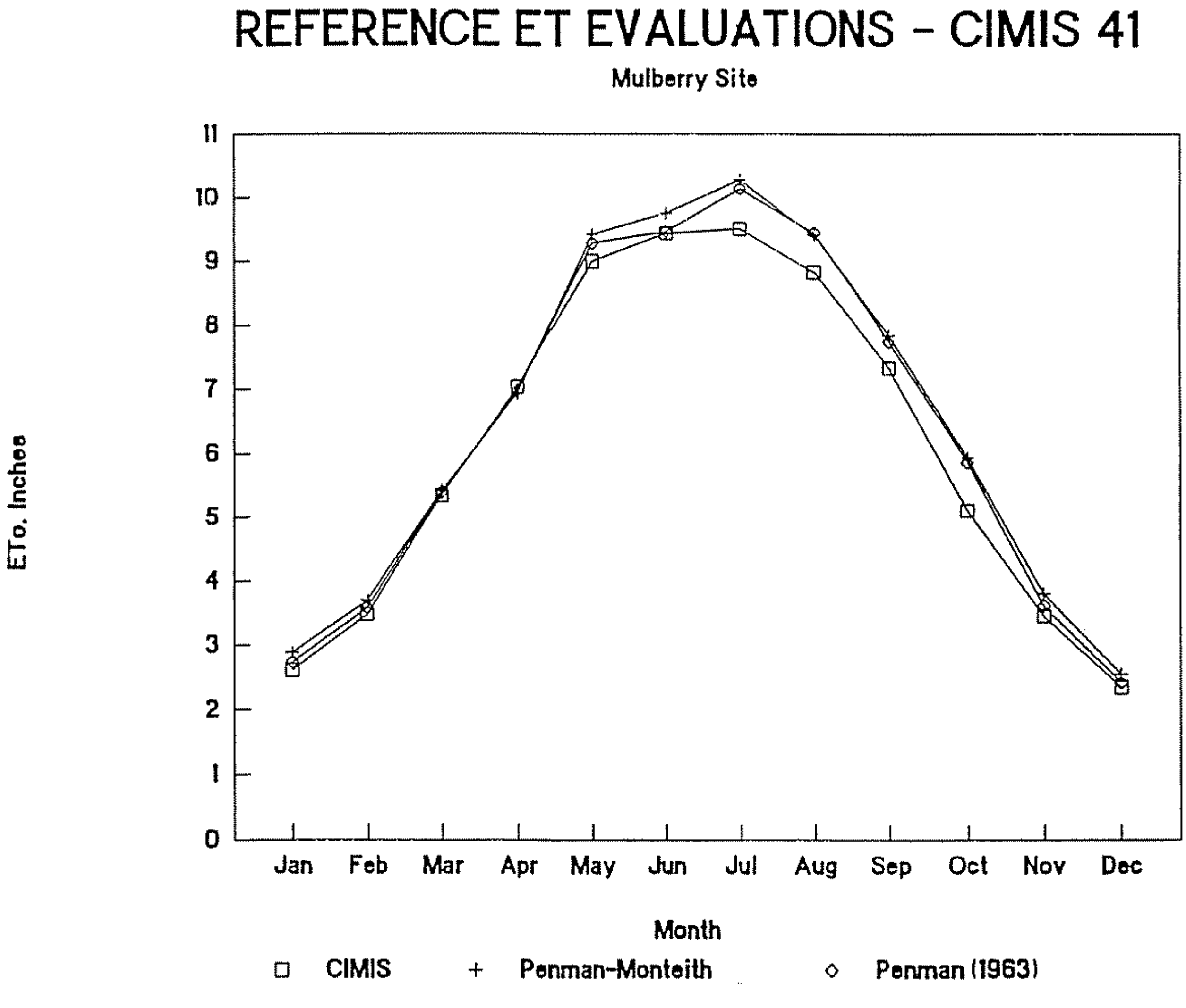


Figure 7. Comparison of mean monthly reference ET for CIMIS Station 41 (Mulberry) computed with the Penman-Monteith and Penman (1963) equations with CIMIS values for the period 1990-1992.

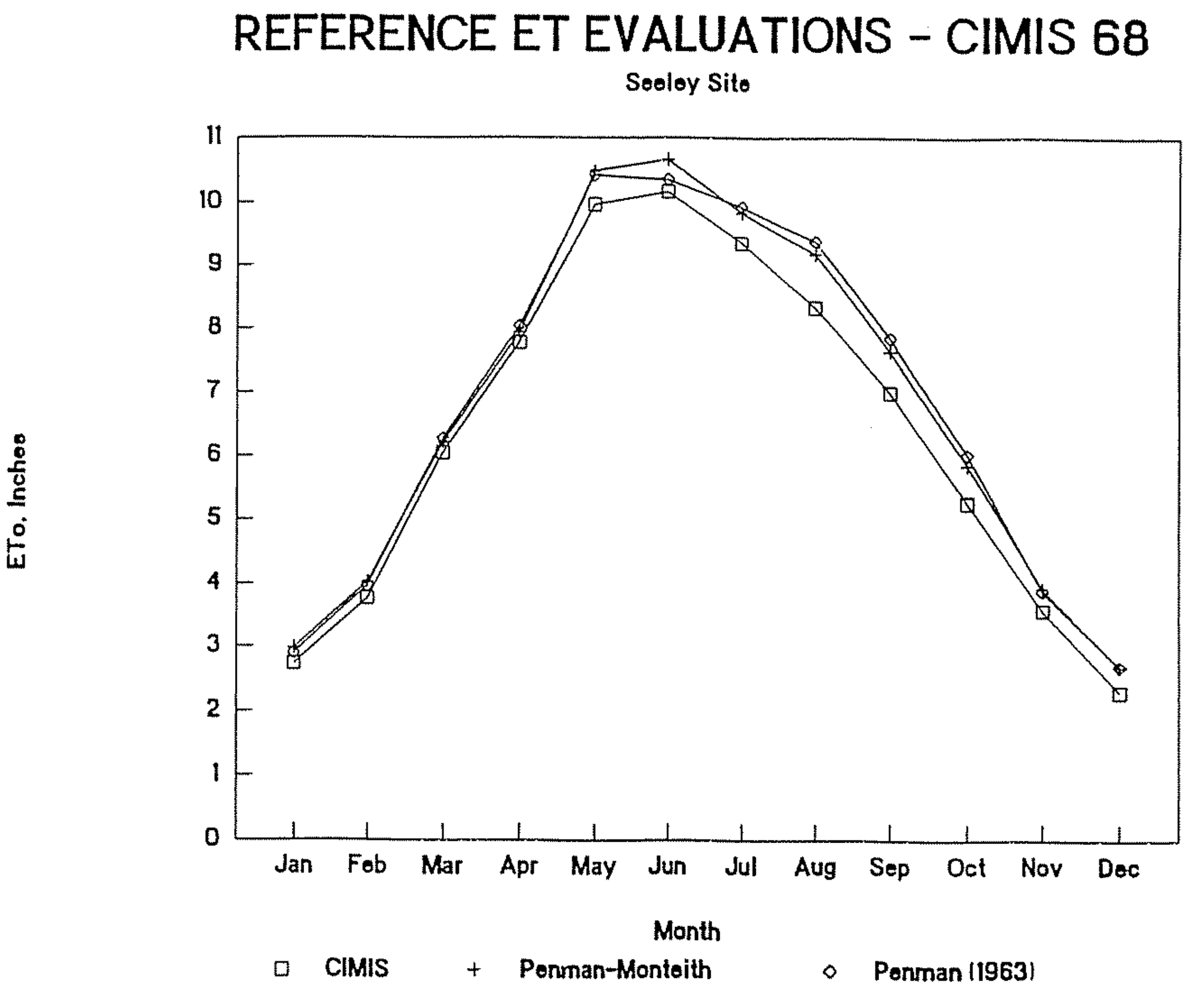


Figure 8. Comparison of mean monthly reference ET for CIMIS Station 68 (Seeley) computed with the Penman-Monteith and Penman (1963) equations with CIMIS values for the period 1990-1992.

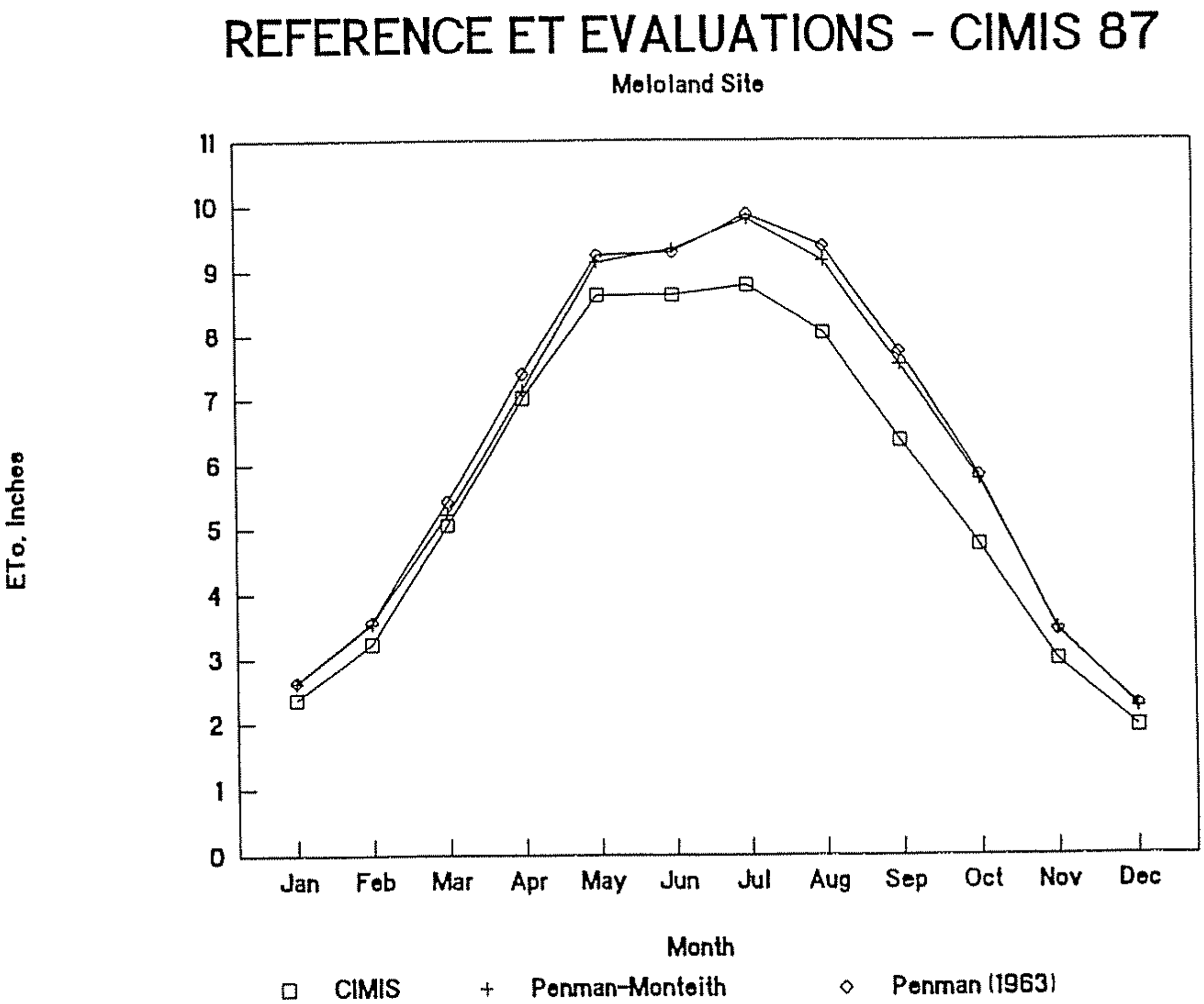


Figure 9. Comparison of mean monthly reference ET for CIMIS Station 87 (Meloland) computed with the Penman-Monteith and Penman (1963) equations with CIMIS values for the period 1990-1992.

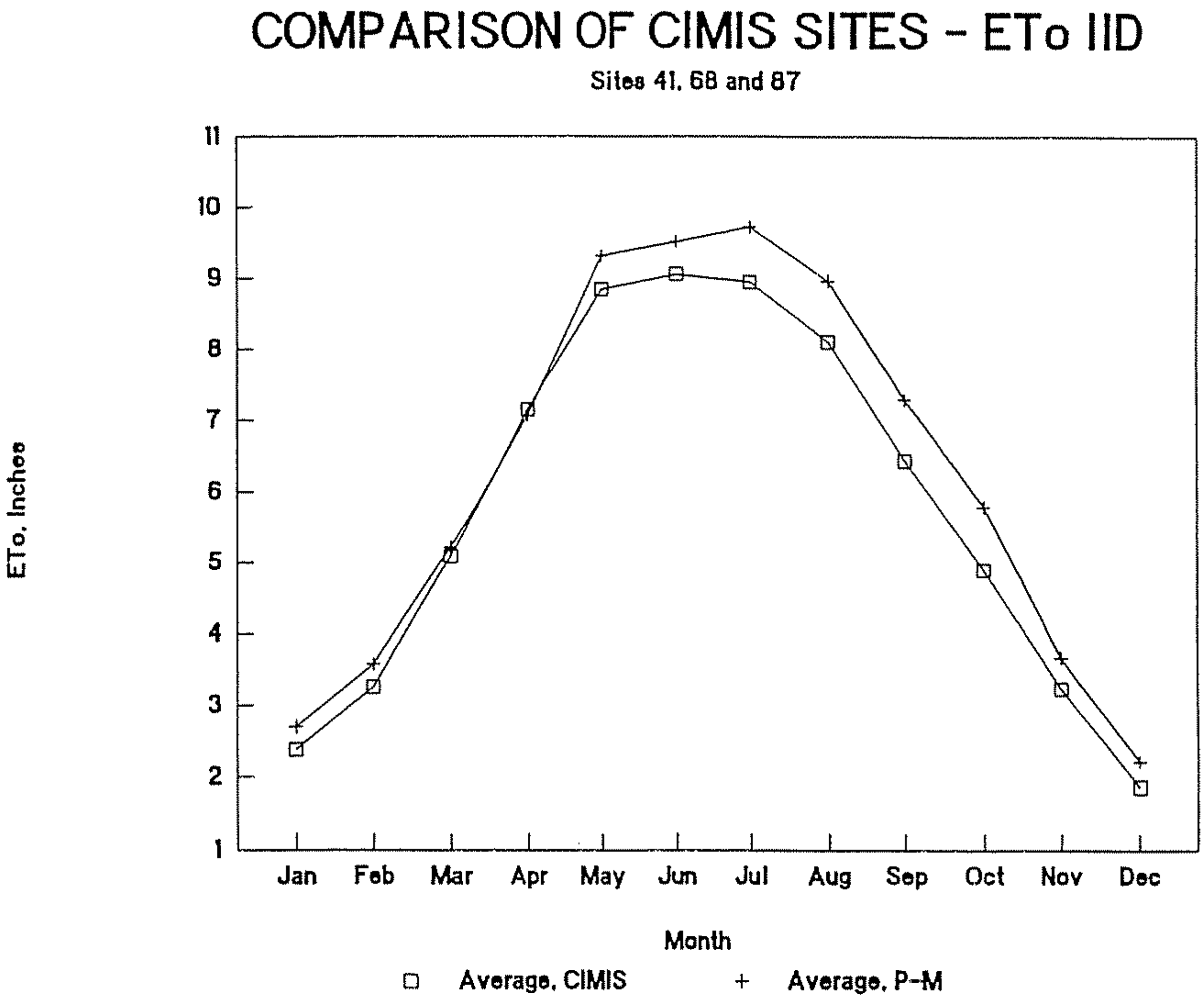


Figure 10. Comparison of mean reference ET estimates for the three CIMIS stations computed with the Penman-Monteith equation with average CIMIS values for the period 1990-1992.

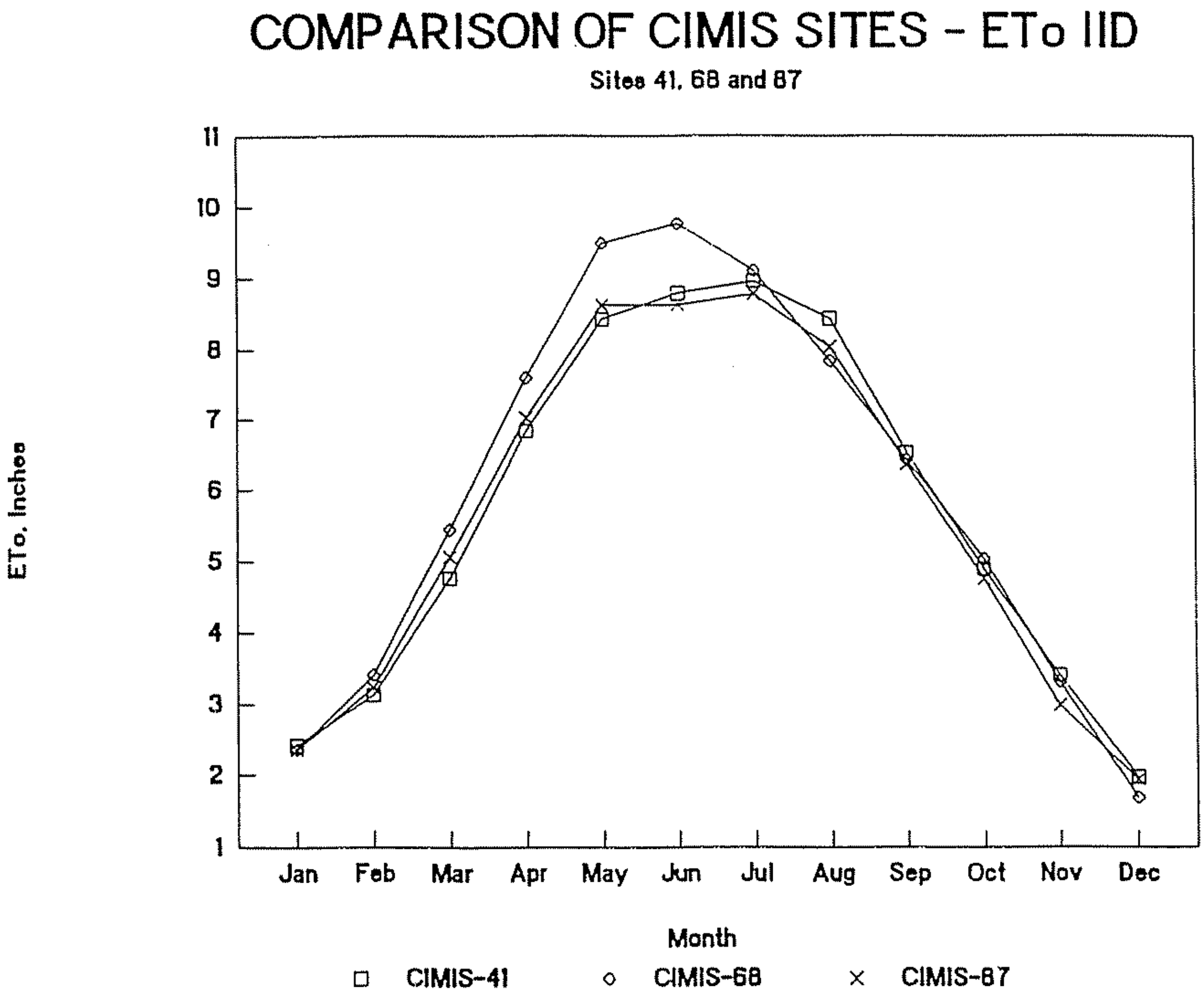


Figure 11. Comparison of mean monthly reference ET at the three sites as indicated by CIMIS values.

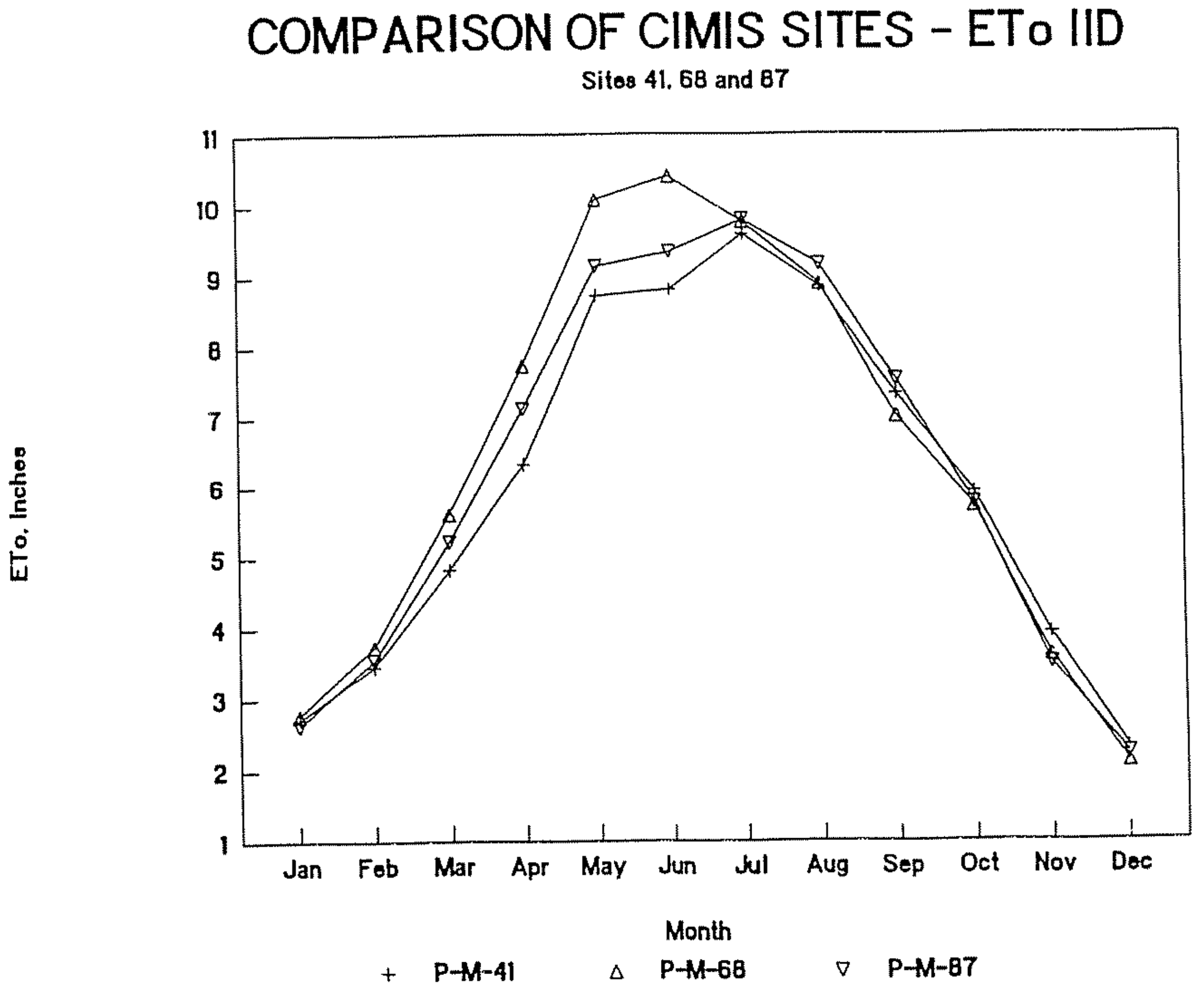


Figure 12. Comparison of mean monthly reference ET at the three sites as indicated by P-M values.

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SUMMARY AND CONCLUSIONS

Mean monthly climatic variables from CIMIS files that are computed without deleting zeros and negative values may have significant errors. The resulting mean values may be significantly lower than means that exclude the zero or negative data. However, CIMIS evaporation (ET_o) are complete because they include estimates for days when climatic data are missing.

Above normal rainfall in 1991 and 1992 in the IID significantly lowered mean annual solar radiation, increased mean annual dewpoint temperature and decreased mean annual wind speed. Changes in these climatic variables significantly affected estimates of annual reference ET based on the Penman-Monteith and Penman (1963) equations.

A spreadsheet program was developed to estimate reference ET for three IID CIMIS sites using the Penman-Monteith and Penman (1963) combination equations and mean monthly climatic data. When comparing estimates for 1990-1992, when data were available for all three sites, the resulting annual estimates of reference ET with the Penman-Monteith and Penman (1963) equations using mean monthly climatic data were consistently about 8-9 percent higher than the CIMIS values. Estimates using hourly or daily climatic data are expected to be closer to CIMIS values because non-linear relationships are involved and mean monthly weather data do result in exactly mean monthly reference ET estimates. More important, the equations used to calculate hourly CIMIS reference ET values were calibrated in California. Therefore, CIMIS ET_o values are recommended for reference ET.

REFERENCES

Allen, R.G., M.E. Jensen, J.L. Wright,and R.D. Burman. 1989. Operational estimates of reference evapotranspiration. Agron. J. 81:650-662.

Dong, A., S.R. Grattan, J.J. Carroll, and C.R.K. Prashar. 1992. Estimation of daytime net radiation over well-watered grass. J. Irrig. and Drain. Div., ASCE, 118(3):466-479.

Jensen, M.E., R.D. Burman, and R.G. Allen (eds). 1990. Evapotranspiration and Irrigation Water Requirements. ASCE Manuals and Reports on Eng. Practice No. 70, New York, 360 pp.

Penman, H.L. 1963. Vegetation and Hydrology. Tech. Comm. No. 53, Commonwealth Bureau of Soils, Harpenden, England, 125 pp.

Solar Energy Research Institute. 1980. Insolation Data Manual. Golden, Colorado.

Smith, M. 1991. Report on the expert consultation on procedures for revision of FAO Guidelines for prediction of crop water requirements. 28-31 May 1990, Rome, 56 pp.

Styles, S. 1993. On-Farm Irrigation Efficiency: Special Technical Report for Imperial Irrigation District. August.

APPENDIX A4-A

EQUATIONS USED TO ESTIMATE REFERENCE ET

Net Radiation

$$R_n = (1 - \alpha) R_s - R_b \tag{A-1}$$

where R_n is net radiation, MJ/(m^2 day), α = albedo, and R_b = net long-wave radiation, MJ/(m^2 day).

Net Long-Wave Radiation

$$R_b = \left(a \frac{R_s}{R_{so}} + b \right) R_{bo} \tag{A-2}$$

where R_b is net long-wave radiation, MJ/(m^2 day), R_s = measured solar radiation, R_{so} = clear-day solar radiation, and for these estimates, a = 1.126 and b = -0.07. Net long-wave radiation on a clear day, R_{bo}, was calculated as follows:

$$R_{bo} = (a_1 + b_1 \sqrt{e_d}) \frac{4.90}{10^9} \frac{(T_x^4 + T_n^4)}{2} \tag{A-3}$$

where $a_1 = 0.26 + 0.1 \exp\{-[0.0154(CD - 177)]^2\}$, CD = calendar day (1-365), and $b_1 = -0.139$ for e_d in kPa.

Albedo

$$\alpha = 0.23 + 0.06 [1 - \cos(\frac{2 \pi CD}{365} - 2.96)] \tag{A-4}$$

where α is albedo and CD = calendar day. Eq. A-4 is essentially the same as that of Wright, page 137, ASCE Manual 70.

Clear-Day Solar Radiation

$$R_{so} = R_a [0.725 + 0.025 \cos(\frac{2 \pi CD}{365} - 2.6)] \tag{A-5}$$

where R_{so} is clear-day solar radiation, R_a = extraterrestrial solar radiation and CD = the calendar day. Eq. A-5 was based on observed high values of solar radiation from CIMIS data and calculated daily R_a values. The range in atmospheric transmissibility ranges from 0.69 in December-January to 0.75 in June-July. FAO uses a constant of 0.75 for R_{so}/R_a (Smith, 1991).

Penman (1963) Equation

$$\lambda ET_o = \frac{\Delta}{\Delta + \gamma}(R_n - G) + \frac{\gamma}{\Delta + \gamma} 6.43\, W_f (e_o - e_d) \qquad \text{(A-6)}$$

where λET_o is the latent heat energy in MJ/(m^2 day), λ = the latent heat of vaporization at mean air temperature, Δ = the slope of the saturation vapor pressure-temperature curve at mean air temperature, γ = the psychrometric constant that is a function of the specific heat of moist air, atmospheric pressure and latent heat of vaporization, R_n = net radiation, G = soil heat flux, $W_f = 1 + 0.536\, u_2$, u_2 = mean daily wind speed in m/s, e_o = saturation vapor pressure at mean air temperature, and e_d = saturation vapor pressure at dewpoint temperature. G, which would be very small for monthly estimates, was assumed to be zero. Equation 7.13 in Manual 70 was used for Δ, 7.15 for γ, and a slight modification of Eq. 7.11 was used for e_o and e_d (Smith, 1991). ET_o in depth units is obtained by dividing by the latent heat of vaporization per unit depth.

Penman-Monteith Equation

$$\lambda ET_o = \frac{\Delta}{\Delta + \gamma *}(R_n - G) + \frac{\lambda}{\Delta + \gamma *}\rho \frac{0.622\lambda}{P} 86{,}400 \frac{(e_o - e_d)}{r_a} \qquad \text{(A-7)}$$

where ρ = the density of moist air, kg/m^3, P = atmospheric pressure, kPa, $\gamma * = \gamma(1 + r_c/r_a)$, r_c = canopy resistance, and r_a = aerodynamic resistance in s/m. The other variables are the same as in Penman's equation except e_o is the mean of the saturation vapor pressure at maximum and minimum air temperatures. The aerodynamic resistance is based on the heights of air temperature, humidity and wind speed measurements as follows (Allen et al., 1989):

$$r_a = \frac{\left[\ln\left(\frac{z_m - d}{z_{om}}\right)\right]\left[\left(\frac{z_h - d}{z_{oh}}\right)\right]}{k^2 u_z} \qquad \text{(A-8)}$$

where r_a has units of s/m, z_m is the height of wind measurement, z_h is the height of air temperature and humidity measurements, d is the zero displacement height above the surface, z_{om} is the roughness length parameter for momentum transfer (m), and z_{oh} is roughness length of the vegetation for vapor and heat transfer, k

= the von Karman constant (0.41), and u_z is the mean wind speed in m/s at height z. A simplified version of Eq. A-7 for either grass or alfalfa reference crop is presented as Eq. 19 and 20 by Allen et al. (1989).

A printout of the equations as used in the spreadsheet is shown on page A4-4.

EQUATIONS USED IN THE SPREADSHEET

ETo, CIMIS-41

```
A19: [W4] +A18+1
B19: [W10] 1987
C19: [W4] 1
D19: [W5] 15
E19: (F2) [W7] 19.55878057
F19: (F0) [W7] +E19/0.041868
G19: (F2) [W7] +E19*(0.725+0.025*@COS(2*@PI*D19/365-2.6))
H19: (F0) [W7] +G19/0.041868
I19: (F0) [W7] 296.6
J19: (F2) [W7] 0.041868*I19
K19: (F2) [W7] +I19/H19
L19: (F1) [W7] 69.322580645
M19: (F1) [W7] (+L19-32)/1.8
N19: (F1) [W7] 34.935483871
O19: (F1) [W7] (+N19-32)/1.8
P19: (F1) [W7] 32.387096774
Q19: (F1) [W7] (+P19-32)/1.8
E98: (F1) [W7] 0.5*(M19+O19)
F98: (F3) [W7] (0.611*@EXP(17.27*M19/(M19+237.3))+0.611*@EXP(17.27*O19/(O19+237.3)))/2
G98: (F3) [W7] 0.611*@EXP(17.27*Q19/(Q19+237.3))
H98: (F3) [W7] 4098*(0.611*@EXP(17.27*E98/(E98+237.3)))/(E98+237.3)^2
I98: (F2) [W7] 2.501-(2.361*10^-3)*E98
J98: (F3) [W7] (1.013*$K$5/(0.622*I98))*10^-3
K98: (F3) [W7] +H98/(H98+J98)
L98: (F3) [W7] 0.23+0.06*(1-@COS(2*@PI*D19/365-2.96))
M98: (F2) [W7] (1-L98)*J19
N98: (F3) [W7] 0.26+0.1*@EXP(-(0.0154*(D19+30-207))^2)
O98: (F2) [W7] (N98-0.139*G98^0.5)*4.9*((M19+273.2)^4+(O19+273.2)^4)/(2*10^9)
P98: (F2) [W7] (1.126*K19-0.07)*O98
Q98: (F2) [W7] +M98-P98
E179: [W7] 31
F179: (F3) [W7] 0.611*@EXP(17.27*E98/(E98+237.3))
G179: (F2) [W7] +K98*Q98
H179: (F2) [W7] (1-K98)*6.43*(1+0.536*S19)*(F179-G98)
I179: (F2) [W7] +G179+H179
J179: (F2) [W7] +I179/I98
K179: (F2) [W7] +E179*J179/25.4
L179: (F3) [W7] (1+($G$11/$N$9)*S19)*J98
M179: (F3) [W7] +H98/(H98+L179)
N179: (F2) [W7] +M179*Q98
O179: [W7] +J98/(H98+L179)
P179: (F2) [W7] +O179*((185370/$N$9)*I98/(E98+273.2))*S19*(F98-G98)
Q179: (F2) [W7] +N179+P179
R179: (F2) [W6] +Q179/I98
S179: (F2) [W6] +E179*R179/25.4
```

APPENDIX A4-B

1. Summary of CIMIS data for three sites in the Imperial Irrigation District showing the differences in mean monthly climatic data between the CIMIS files after deleting zeros with the mean values reported by Styles (4 pages).

2. Relationship between clear-day solar radiation and extraterrestrial solar radiation as indicated by mean observed values and as represented by Eq. A-5.

3. Estimated albedo used in estimating daily net radiation based on the data of Wright, ASCE Manual 70, page 137.

4. Tabular summary of annual reference ET values as indicated by CIMIS and by the Penman-Monteith and Penman (1963) estimating methods (1 page).

5. Tabular summary of mean monthly reference ET values as indicated by CIMIS and by the Penman-Monteith and Penman (1963) estimating methods.

7. Copies of the spreadsheet results for one of three sites, CIMIS 41, (6 pages).

22-Feb-94 SUMMARY OF IID CIMIS DATA \IID-SUM

EVAPORATION (ETo) DATA FROM CIMIS/STYLES FILES, STATION 41, Mulberry:

SUMMARY BY YEARS - CIMIS #41, Evap, in/day

(Values from Styles Disk)

Year	1987	1988	1989	1990	1991	1992	Avg
Average	0.226	0.212	0.205	0.197	0.185	0.180	0.201
Apr-Sep values	0.323	0.277	0.289	0.274	0.257	0.255	0.279
Annual total, in.	82.5	77.4	74.8	72.0	67.6	65.6	73.3

(Styles, 1993; p. A-52 - A53)

Month	1987	1988	1989	1990	1991	1992	Avg
Average	6.90	6.48	6.26	6.01	5.65	5.48	6.13
Apr-Sep values	0.323	0.276	0.290	0.274	0.258	0.254	0.279
Annual total, in.	82.8	77.7	75.1	72.1	67.8	65.8	73.6

SOLAR RADIATION FROM CIMIS/STYLES FILES, STATION 41, Mulberry:

SUMMARY BY YEARS - CIMIS #41, ly/day

(Values from Styles' Disk)

Year	1987	1988	1989	1990	1991	1992	Avg
Average	501.4	500.4	509.3	497.5	480.1	471.9	493.4
Average, Apr-Sep	645.0	629.2	643.6	632.3	627.8	607.4	630.9

(Styles, 1993; p. A-52 - A53)

Year	1987	1988	1989	1990	1991	1992	Avg
Average	494.2	475.3	499.9	450.5	460.3	444.1	470.7
Average, Apr-Sep	638.7	589.0	643.6	560.5	605.3	560.2	599.5
Ratios (Styles/Actual)							
Average	0.986	0.950	0.982	0.905	0.959	0.941	0.954
Average, Apr-Sep	0.990	0.936	1.000	0.886	0.964	0.922	0.950

MAXIMUM TEMPERATURES FROM CIMIS/STYLES FILES, STATION 41, Mulberry:

SUMMARY BY YEARS - CIMIS #41, Maximum Temp, F

(Values from Styles' Disk)

Year	1987	1988	1989	1990	1991	1992	Avg
Average	88.1	88.9	90.4	87.5	85.9	86.9	87.9
(Styles, 1993; p. A-52 - A53)							
Average	86.1	85.3	87.8	82.7	82.8	82.7	84.6
Ratios (Styles/Actual)							
	0.977	0.959	0.971	0.946	0.964	0.951	0.961

MINIMUM TEMPERATURES FROM CIMIS/STYLES FILES, STATION 41, Mulberry:

SUMMARY BY YEARS - CIMIS #41, Minimum Temp, F

(Values from Styles' Disk) Year

Year	1987	1988	1989	1990	1991	1992	Avg
Average	53.7	53.2	52.7	53.1	54.1	55.8	53.8
(Styles, 1993; p. A-52 - A53)							
Average	52.3	51.0	51.4	50.1	52.3	53.1	51.7
Ratios (Styles/Actual)							
Average	0.975	0.959	0.975	0.943	0.966	0.951	0.961

IID CIMIS DATA

DEWPOINT TEMPERATURE FROM CIMIS/STYLES, STATION 41, Mulberry:

SUMMARY BY YEARS - CIMIS #41, Dewpoint, F

Year	1987	1988	1989	1990	1991	1992	Avg
(Values from Styles' Disk)							
Average	45.0	47.0	44.8	46.7	49.5	52.7	47.6
(Styles, 1993; p. A-52 - A53)							
Average	44.0	45.2	43.4	43.8	47.1	50.2	45.6
Ratios (Styles/Actual)							
Average	0.980	0.962	0.971	0.937	0.952	0.952	0.959

WIND RUN FROM CIMIS/STYLES STATION 41, Mulberry:

SUMMARY BY YEARS - CIMIS #41, Wind run, mi/day

Year	1987	1988	1989	1990	1991	1992	Avg
(Values from Styles' Disk)							
Average	125.5	125.5	122.4	121.1	120.0	110.0	120.7
(Styles, 1993; p. A-52 - A53)							
Average	124.0	120.4	120.4	115.6	115.5	105.4	116.9
Ratios (Styles/Actual)							
Average	0.988	0.959	0.983	0.955	0.963	0.958	0.968

EVAPORATION (ETo) DATA FROM CIMIS/STYLES FILES, STATION 68, Seeley:

(Tabular values not available in Styles, 1993)

SUMMARY BY YEARS - CIMIS #68, Evap, in/day

(Values from Styles' Disk)

Year	1987	1988	1989	1990	1991	1992	Avg
Average		0.225	0.231	0.211	0.190	0.186	0.209
Avg, Apr-Sep		0.297	0.317	0.291	0.267	0.265	0.287

SOLAR RADIATION FROM CIMIS/STYLES FILES, STATION 68, Seeley:

SUMMARY BY YEARS - CIMIS #68, Rs, ly/day

(Values from Styles' Disk) Year

Year	1987	1988	1989	1990	1991	1992	Avg
Average		517.9	511.6	500.1	493.8	492.0	503.1
Avg, Apr-Sep		646.8	643.2	627.5	633.2	631.2	636.4

MAXIMUM TEMPERATURES FROM CIMIS/STYLES FILES, STATION 68, Seeley:

SUMMARY BY YEARS - CIMIS #68, Maximum Temp, F

(Values from Styles' Disk)

Year	1987	1988	1989	1990	1991	1992	Avg
Average		88.7	89.9	88.0	86.0	86.6	87.8
Avg, Apr-Sep		98.4	100.2	98.5	95.7	98.5	98.2

MINIMUM TEMPERATURES FROM CIMIS/STYLES FILES, STATION 68, Seeley:

SUMMARY BY YEARS - CIMIS #68, Minimum Temp, F

(Values from Styles' Disk)

Year	1987	1988	1989	1990	1991	1992	Avg
Average		54.4	54.2	54.5	55.0	56.3	54.9
Avg, Apr-Sep		63.9	64.9	65.9	63.9	66.9	65.1

IID CIMIS DATA

DEWPOINT TEMPERATURE FROM CIMIS/STYLES, STATION 68, Seeley:

SUMMARY BY YEARS - CIMIS #68, Dewpoint Temp, F

(Values from Styles' Disk) Year

Year	1987	1988	1989	1990	1991	1992	Avg
Average		41.2	39.3	43.3	50.2	48.8	44.5
Avg, Apr-Sep		47.9	46.0	51.2	55.9	57.3	51.7

WIND RUN FROM CIMIS/STYLES STATION 68, Seeley:

SUMMARY BY YEARS - CIMIS #68, Wind run, mi/day

(Values from Styles' Disk)

Year	1987	1988	1989	1990	1991	1992	Avg
Average		123.4	130.9	133.4	120.6	100.3	121.7
Avg, Apr-Sep		132.6	148.6	152.7	137.1	121.6	138.5

EVAPORATION (ETo) DATA FROM CIMIS/STYLES FILES, STATION 87, Meloland:

SUMMARY BY YEARS - CIMIS #87, Evap, in/day

(Values from Styles' Disk) Year

Year	1987	1988	1989	1990	1991	1992	Avg
Average				0.198	0.175	0.183	0.185
Avg Apr-Sep				0.274	0.242	0.261	0.259
(Styles, 1993; p. A-49)							
Average				6.06	5.33	5.58	5.66
Ratios (Styles/Actual)				0.996	0.999	0.996	0.997

SOLAR RADIATION FROM CIMIS/STYLES FILES, STATION 87, Meloland:

SUMMARY BY YEARS - CIMIS #87, Solar rad, ly/d

(Values from Styles' Disk)

Year	1987	1988	1989	1990	1991	1992	Avg
Average				496.1	480.5	479.3	485.3
Apr-Sep				624.4	615.8	611.1	617.1
(Styles, 1993; p. A-49)							
Average				491.7	480.0	479.3	483.6
Apr-Sep				617.8	615.8	611.2	614.9
Ratios (Styles/Actual).							
Average				0.991	0.999	1.000	0.997
Apr-Sep				0.990	1.000	1.000	0.996

MAXIMUM TEMPERATURES FROM CIMIS/STYLES FILES, STATION 87, Meloland:

SUMMARY BY YEARS - CIMIS #87, Max Temp, F

(Values from Styles' Disk) Year

Year	1987	1988	1989	1990	1991	1992	Avg
Average				87.6	86.2	87.4	87.0
(Styles, 1993; p. A-49)							
Average				87.3	85.7	87.4	86.8
Ratios (Styles/Actual)				0.997	0.995	1.000	0.997

IID CIMIS DATA

MINIMUM TEMPERATURES FROM CIMIS/STYLES FILES, STATION 87, Meloland:

SUMMARY BY YEARS - CIMIS #87, Min Temperature, F

Year	1987	1988	1989	1990	1991	1992	Avg
(Values from Styles' Disk)							
Average				54.9	55.1	57.0	55.7
(Styles, 1993; p. A-49)							
Average				54.4	54.5	56.7	55.2
Ratios (Styles/Actual)				0.990	0.988	0.995	0.991

DEWPOINT TEMPERATURE FROM CIMIS/STYLES, STATION 87, Meloland:

SUMMARY BY YEARS - CIMIS #87, Dewpoint, F

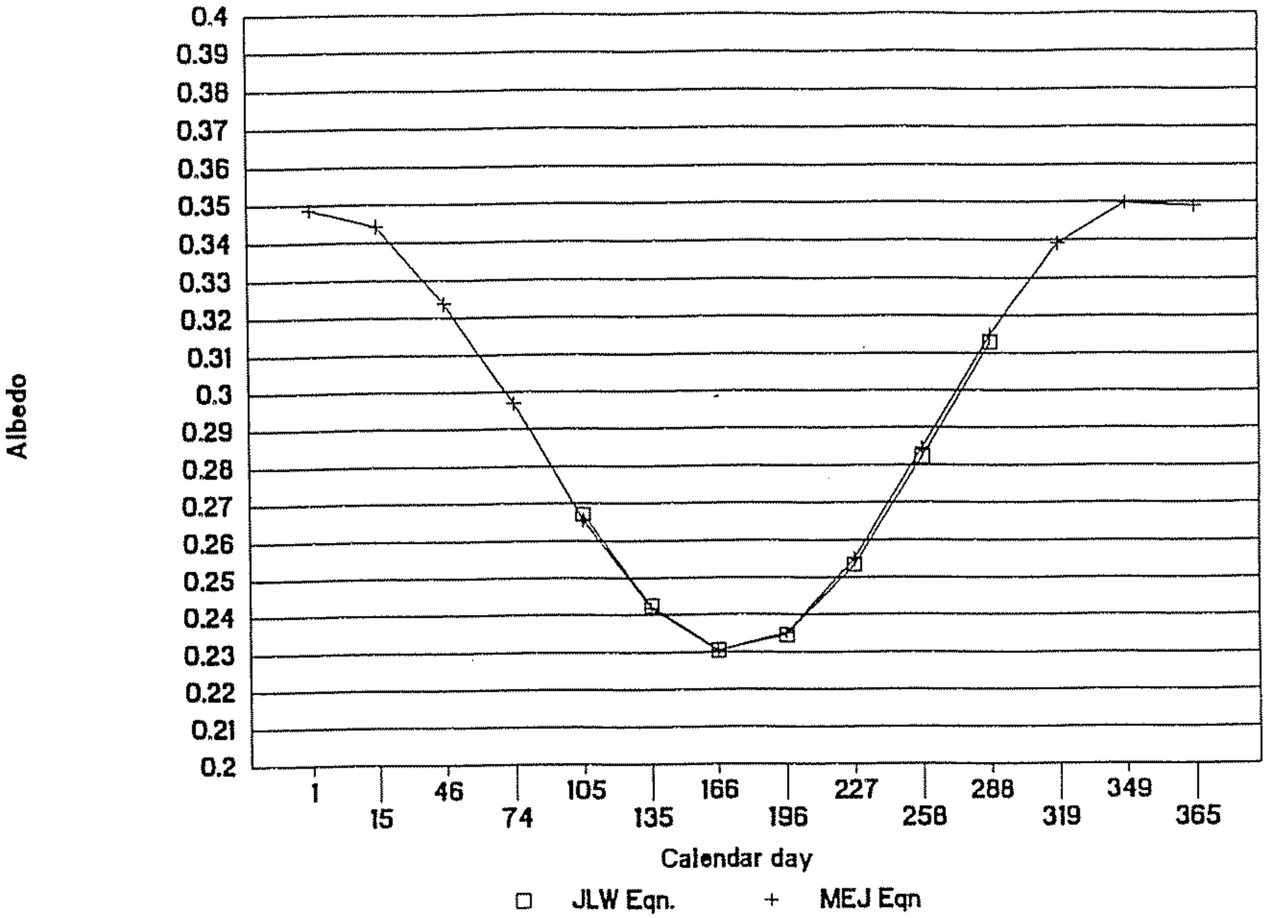
Year	1987	1988	1989	1990	1991	1992	Avg
(Values from Styles' Disk)							
Average			45.4	53.2	51.4	50.0	
(Styles, 1993; p. A-49)							
Average			45.3	52.7	49.5	49.2	
Ratios (Styles/Actual)				0.998	0.992	0.963	0.984

WIND RUN FROM CIMIS/STYLES STATION 87, Meloland:

SUMMARY BY YEARS - CIMIS #87, Wind run, mi/d

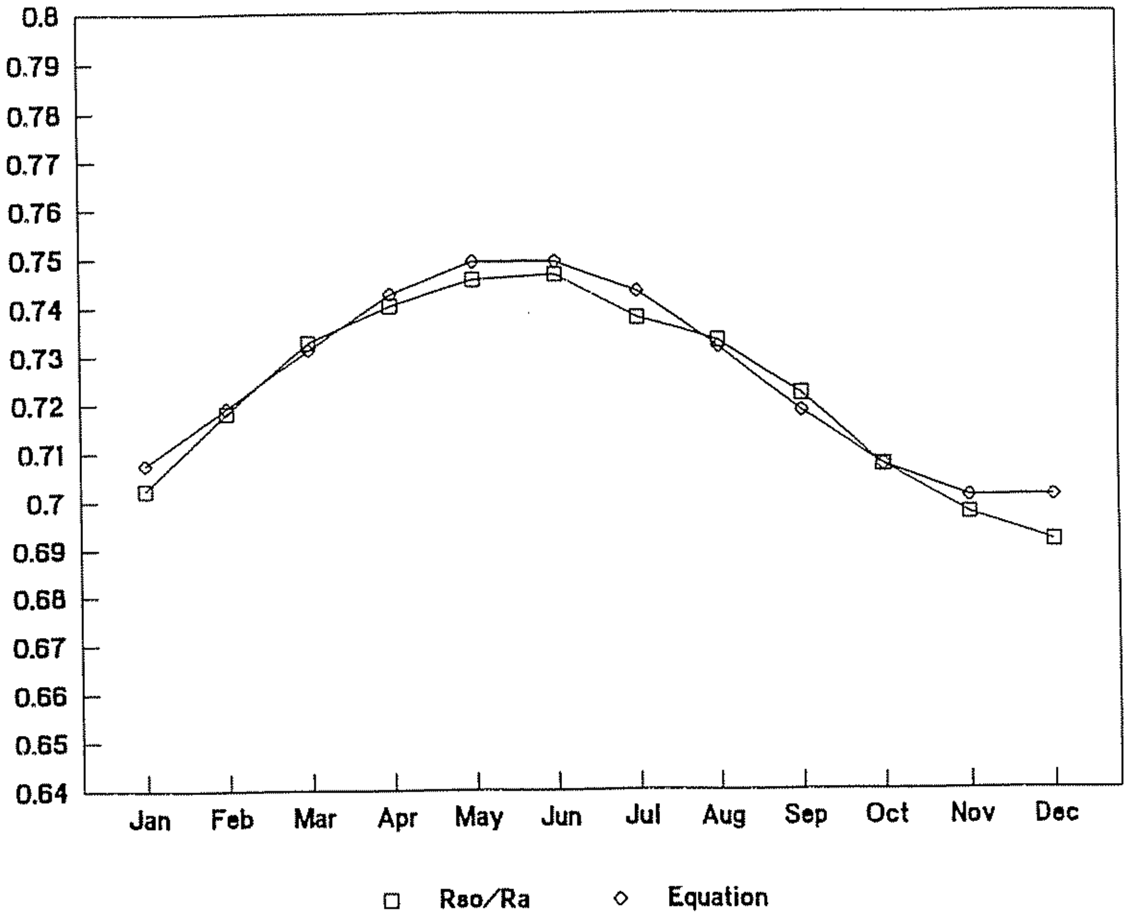
Year	1987	1988	1989	1990	1991	1992	Avg
(Values from Styles' Disk)							
Average				122.3	116.1	104.6	114.3
(Styles, 1993; p. A-49)							
Average				122.3	115.9	104.6	114.3
Ratios (Styles/Actual)				1.000	0.998	1.000	0.999

ESTIMATED ALBEDO



SOLAR RADIATION - IID

Ratio, Clear Day/Potential



22-Feb-94 ESTIMATES OF IMPERIAL VALLEY ETo - 1987-1992 "CORRECTED" \ETO-IVAL

Year	Station	Penman-Monteith		Styles CIMIS		Penman (1963)		Average	
1987	C41 Mulberry	82.7		82.6		81.0		82.1	
	C68 Seeley								
	C87 Meloland								
	Average	82.7		82.6		81.0		82.1	
1988	C41 Mulberry	80.8		77.7		78.4		79.0	
	C68 Seeley	85.5		82.6		84.8		84.3	
	C87 Meloland								
	Average	83.2		80.2		81.6		81.6	
1989	C41 Mulberry	85.6		75.0		82.2		80.9	
	C68 Seeley	89.5		84.5		87.5		87.2	
	C87 Meloland								
	Average	87.6		79.8		84.9		84.1	
1990	C41 Mulberry	75.8		72.2		74.6		74.2	
	C68 Seeley	85.6		77.1		84.5		82.4	
	C87 Meloland	81.2		72.6		81.1		78.3	
	Average	80.9		74.0		80.1		78.3	
1991	C41 Mulberry	72.7		67.8		73.2		71.2	
	C68 Seeley	74.4		69.4		76.2		73.3	
	C87 Meloland	70.7		63.9		72.3		69.0	
	Average	72.6		67.0		73.9		71.2	
1992	C41 Mulberry	69.7		65.8		70.5		68.7	
	C68 Seeley	72.3		67.9		75.7		72.0	
	C87 Meloland	73.0		66.9		74.9		71.6	
	Average	71.7		66.9		73.7		70.7	
All years	C41 Mulberry	77.9		73.5		76.7		76.0	
	C68 Seeley	81.5		76.3		81.7		79.8	
	C87 Meloland	75.0		67.8		76.1		73.0	
	Average	78.1	100.0%	72.5	100.0%	78.2	100.0%	76.3	100.0%
All years: Avg of avgs		79.8	102.2%	75.1	96.2%	79.2	101.5%	78.0	100.0%
For years 1990-1992	1990	80.9	107.8%	74.0	106.8%	80.1	105.5%	78.3	106.7%
	1991	72.6	96.7%	67.0	96.7%	73.9	97.4%	71.2	97.0%
	1992	71.7	95.5%	66.9	96.5%	73.7	97.1%	70.7	96.4%
	Average	75.0	100.0%	69.3	100.0%	75.9	100.0%	73.4	100.0%
Percent of 1990-1992 average:			102.2		94.4		103.4	100.0	
Percent of CIMIS average:			108.3		100.0		109.5		
1990	Variability between estimates:			Std dev	& CV, %			3.08	3.8
1991								2.98	4.1
1992								2.86	4.0

	CIMIS SITE 41, Eto			CIMIS SITE 68, Eto			CIMIS SITE 87, Eto			Overall
Month	CIMIS	P-M	Penman	CIMIS	P-M	Penman	CIMIS	P-M	Penman	average
	In/mo	In/mo	In/mo	In/mo	In/mo	In/mo	In/mo	In/mo	In/mo	In/mo
Jan	2.42	2.89	2.74	2.36	2.97	2.90	2.37	2.62	2.64	2.66
Feb	3.13	3.69	3.58	3.42	4.03	3.97	3.24	3.55	3.57	3.57
Mar	4.76	5.42	5.40	5.45	6.21	6.28	5.06	5.22	5.42	5.47
Apr	6.83	6.93	6.98	7.60	7.94	8.04	7.02	7.13	7.40	7.32
May	8.43	9.41	9.28	9.49	10.49	10.43	8.63	9.13	9.24	9.39
Jun	8.79	9.75	9.46	9.76	10.66	10.35	8.63	9.34	9.29	9.56
Jul	8.96	10.27	10.14	9.11	9.83	9.93	8.78	9.80	9.86	9.63
Aug	8.44	9.40	9.44	7.85	9.19	9.39	8.04	9.16	9.38	8.92
Sep	6.53	7.84	7.74	6.43	7.65	7.85	6.37	7.54	7.74	7.30
Oct	4.89	5.94	5.87	5.03	5.85	6.02	4.75	5.76	5.82	5.55
Nov	3.41	3.80	3.61	3.32	3.93	3.88	2.99	3.49	3.44	3.54
Dec	1.97	2.55	2.42	1.68	2.69	2.70	1.94	2.23	2.28	2.27
Average	68.6	77.9	76.7	71.5	81.5	81.7	67.8	75.0	76.1	75.2
Pct, CIMIS	100.0	113.6	111.8	100.0	113.9	114.3	100.0	110.6	112.2	
Grouped average							69.3	78.1	78.2	
Pct, CIMIS							100.0	112.7	112.8	

22-Feb-94 ESTIMATED REFERENCE ET - IID \ETO-CM41

Row ==

3 Column = C D E F G H I J K L M N O P Q R S

4 SITE INPUT DATA: Lat, degrees = 33.00 or 0.5759 Radians

5 Elevation, m = -50 m Atm. pressure 101.90 kPa Energy units = MJ/(m^2 day) = MJ*

6 Measurement height: Temp & dewpoin 2.00 m Wind 2.00 m

7 Reference crop: Grass

8 hc = 0.12 m

9 zom = 0.0147 m zov = 0.1zom= 1E-03 m 207.7

10 d = 0.0800 m LAI = 2.88 ra = -----

11 rc = 69.44 s/m u2

12 Clear day solar radiation = Ra x [0.725 + 0.025 cos(2 Pi CD/365 - 2.6)] Based on maximum Rs values

13 --

14 INPUT DATA: SITE:CIMIS Station 41, Mulberry

15

Row	Year	Mo	CD	Ra	Ra	Rso	Rso	Rs	Rs		Maximum temp		Minimum temp		Dewpoint temp		Wind run	
17	Year	Mo	CD	MJ*	ly/day	MJ*	ly/day	ly/day	MJ*	n/N	deg F	deg C	deg F	deg C	deg F	deg C	mi/day	m/s
18																		
19	1987	1	15	19.56	467	13.84	331	297	12.42	0.90	69.3	20.7	34.9	1.6	32.4	0.2	108	2.01
20	1987	2	46	24.41	583	17.55	419	378	15.83	0.90	73.5	23.0	41.4	5.2	36.6	2.5	138	2.56
21	1987	3	74	30.65	732	22.41	535	508	21.28	0.95	77.5	25.3	43.0	6.1	38.1	3.4	145	2.71
22	1987	4	105	36.31	867	26.97	644	627	26.25	0.97	91.4	33.0	52.3	11.3	41.7	5.4	124	2.31
23	1987	5	135	39.96	954	29.93	715	671	28.09	0.94	93.6	34.2	58.6	14.8	42.8	6.0	154	2.86
24	1987	6	166	41.36	988	30.98	740	713	29.86	0.96	105.3	40.7	66.2	19.0	40.1	4.5	136	2.54
25	1987	7	196	40.60	970	30.16	720	701	29.35	0.97	105.4	40.8	69.8	21.0	51.3	10.7	140	2.60
26	1987	8	227	37.69	900	27.57	658	603	25.26	0.92	104.9	40.5	74.2	23.4	61.3	16.3	154	2.87
27	1987	9	258	32.84	784	23.59	563	517	21.63	0.92	100.6	38.1	62.7	17.0	50.2	10.1	124	2.31
28	1987	10	288	26.70	638	18.89	451	360	15.09	0.80	94.0	34.5	60.6	15.9	59.2	15.1	99	1.84
29	1987	11	319	21.02	502	14.73	352	313	13.09	0.89	77.2	25.1	44.9	7.1	47.9	8.8	82	1.54
30	1987	12	349	18.14	433	12.72	304	243	10.16	0.80	65.0	18.4	35.6	2.0	37.9	3.3	103	1.91
31	1988	1	15	19.56	467	13.84	331	293	12.27	0.89	69.3	20.7	35.5	1.9	37.1	2.8	106	1.98
32	1988	2	46	24.41	583	17.55	419	393	16.47	0.94	76.7	24.8	40.2	4.6	41.3	5.2	108	2.02
33	1988	3	74	30.65	732	22.41	535	461	19.30	0.86	82.3	28.0	43.3	6.3	38.7	3.7	125	2.33
34	1988	4	105	36.31	867	26.97	644	544	22.78	0.84	84.7	29.3	48.2	9.0	47.2	8.5	126	2.35
35	1988	5	135	39.96	954	29.93	715	573	24.01	0.80	93.1	34.0	54.5	12.5	42.6	5.9	186	3.46
36	1988	6	166	41.36	988	30.98	740	701	29.35	0.95	101.5	38.6	62.7	17.1	49.8	9.9	136	2.54
37	1988	7	196	40.60	970	30.16	720	661	27.65	0.92	106.5	41.4	73.9	23.3	64.2	17.9	149	2.77
38	1988	8	227	37.69	900	27.57	658	624	26.14	0.95	105.1	40.6	73.2	22.9	62.9	17.2	124	2.31
39	1988	9	258	32.84	784	23.59	563	431	18.03	0.76	102.5	39.2	66.2	19.0	52.0	11.1	119	2.21
40	1988	10	288	26.70	638	18.89	451	421	17.61	0.93	96.0	35.6	61.2	16.2	55.7	13.2	102	1.90
41	1988	11	319	21.02	502	14.73	352	310	12.98	0.88	78.5	25.8	44.3	6.8	40.5	4.7	114	2.12
42	1988	12	349	18.14	433	12.72	304	291	12.18	0.96	70.3	21.3	34.9	1.6	31.8	-0.1	111	2.06
43	1989	1	15	19.56	467	13.84	331	285	11.93	0.86	69.1	20.6	34.8	1.5	32.7	0.4	101	1.89
44	1989	2	46	24.41	583	17.55	419	395	16.52	0.94	75.0	23.9	39.2	4.0	40.2	4.6	123	2.28
45	1989	3	74	30.65	732	22.41	535	429	17.98	0.80	88.3	31.3	47.6	8.7	47.7	8.7	113	2.10
46	1989	4	105	36.31	867	26.97	644	633	26.50	0.98	92.4	33.6	53.1	11.7	48.6	9.2	120	2.24
47	1989	5	135	39.96	954	29.93	715	693	29.00	0.97	95.3	35.2	57.0	13.9	41.4	5.2	161	3.00
48	1989	6	166	41.36	988	30.98	740	713	29.84	0.96	104.8	40.5	62.8	17.1	41.8	5.4	146	2.72
49	1989	7	196	40.60	970	30.16	720	656	27.48	0.91	108.5	42.5	71.5	21.9	53.2	11.8	141	2.63
50	1989	8	227	37.69	900	27.57	658	624	26.14	0.95	104.4	40.2	70.4	21.3	61.5	16.4	129	2.40
51	1989	9	258	32.84	784	23.59	563	543	22.72	0.96	102.7	39.3	65.3	18.5	50.3	10.1	128	2.37
52	1989	10	288	26.70	638	18.89	451	420	17.60	0.93	91.3	32.9	54.8	12.7	44.5	6.9	113	2.11
53	1989	11	319	21.02	502	14.73	352	334	13.96	0.95	81.1	27.3	43.0	6.1	40.4	4.6	103	1.93
54	1989	12	349	18.14	433	12.72	304	274	11.47	0.90	71.9	22.2	32.8	0.5	34.9	1.6	90	1.69

55	1990	1	15	19.56	467	13.84	331	244	10.20	0.74	72.3	22.4	34.8	1.5	37.1	2.8	103	1.91
56	1990	2	46	24.41	583	17.55	419	362	15.16	0.86	73.0	22.8	36.1	2.3	36.6	2.6	123	2.29
57	1990	3	74	30.65	732	22.41	535	490	20.52	0.92	81.3	27.4	44.8	7.1	43.8	6.5	132	2.46
58	1990	4	105	36.31	867	26.97	644	490	20.50	0.76	86.6	30.3	52.5	11.4	50.6	10.3	125	2.32
59	1990	5	135	39.96	954	29.93	715	660	27.63	0.92	92.2	33.4	55.4	13.0	41.9	5.5	162	3.03
60	1990	6	166	41.36	988	30.98	740	672	28.14	0.91	103.5	39.7	64.3	17.9	48.9	9.4	121	2.26
61	1990	7	196	40.60	970	30.16	720	579	24.24	0.80	105.5	40.8	74.1	23.4	61.3	16.3	144	2.68
62	1990	8	227	37.69	900	27.57	658	425	17.77	0.64	101.1	38.4	72.2	22.3	63.2	17.3	117	2.17
63	1990	9	258	32.84	784	23.59	563	538	22.52	0.95	99.7	37.6	68.7	20.4	62.5	17.0	112	2.09
64	1990	10	288	26.70	638	18.89	451	439	18.39	0.97	91.1	32.8	55.5	13.0	49.7	9.8	94	1.74
65	1990	11	319	21.02	502	14.73	352	246	10.29	0.70	77.0	25.0	44.8	7.1	36.9	2.7	114	2.12
66	1990	12	349	18.14	433	12.72	304	262	10.97	0.86	66.6	19.2	34.2	1.2	28.2	-2.1	107	2.00
67	1991	1	15	19.56	467	13.84	331	209	8.77	0.63	67.6	19.8	38.4	3.5	35.2	1.8	90	1.68
68	1991	2	46	24.41	583	17.55	419	356	14.91	0.85	78.4	25.8	42.9	6.0	46.2	7.9	101	1.88
69	1991	3	74	30.65	732	22.41	535	450	18.83	0.84	71.7	22.0	43.4	6.3	43.1	6.2	145	2.70
70	1991	4	105	36.31	867	26.97	644	599	25.07	0.93	83.3	28.5	48.0	8.9	46.9	8.3	140	2.61
71	1991	5	135	39.96	954	29.93	715	699	29.24	0.98	89.2	31.8	53.3	11.8	50.7	10.4	145	2.71
72	1991	6	166	41.36	988	30.98	740	574	24.02	0.78	96.3	35.7	62.2	16.8	55.4	13.0	132	2.46
73	1991	7	196	40.60	970	30.16	720	655	27.41	0.91	102.3	39.1	69.7	20.9	62.9	17.2	122	2.27
74	1991	8	227	37.69	900	27.57	658	611	25.59	0.93	104.2	40.1	73.4	23.0	62.3	16.8	122	2.27
75	1991	9	258	32.84	784	23.59	563	495	20.70	0.88	99.7	37.6	70.4	21.4	63.8	17.7	113	2.11
76	1991	10	288	26.70	638	18.89	451	400	16.73	0.89	93.5	34.2	60.3	15.7	53.9	12.2	121	2.25
77	1991	11	319	21.02	502	14.73	352	255	10.66	0.72	77.6	25.3	46.0	7.8	31.8	-0.1	121	2.25
78	1991	12	349	18.14	433	12.72	304	222	9.31	0.73	66.5	19.2	41.6	5.3	41.6	5.3	87	1.61
79	1992	1	15	19.56	467	13.84	331	272	11.38	0.82	68.6	20.3	37.5	3.1	37.8	3.2	91	1.70
80	1992	2	46	24.41	583	17.55	419	339	14.20	0.81	74.0	23.4	45.7	7.6	47.0	8.4	106	1.97
81	1992	3	74	30.65	732	22.41	535	426	17.83	0.80	75.1	23.9	46.8	8.2	51.1	10.6	98	1.82
82	1992	4	105	36.31	867	26.97	644	493	20.64	0.77	89.2	31.8	53.6	12.0	52.7	11.5	92	1.71
83	1992	5	135	39.96	954	29.93	715	636	26.61	0.89	93.6	34.2	61.2	16.2	58.0	14.5	110	2.04
84	1992	6	166	41.36	988	30.98	740	627	26.24	0.85	99.9	37.7	64.0	17.8	58.6	14.8	127	2.37
85	1992	7	196	40.60	970	30.16	720	633	26.49	0.88	103.8	39.9	73.8	23.2	65.0	18.4	135	2.51
86	1992	8	227	37.69	900	27.57	658	584	24.46	0.89	105.1	40.6	78.1	25.6	69.7	20.9	145	2.70
87	1992	9	258	32.84	784	23.59	563	389	16.30	0.69	104.0	40.0	71.0	21.7	61.4	16.3	108	2.01
88	1992	10	288	26.70	638	18.89	451	389	16.27	0.86	92.0	33.3	60.5	15.8	54.8	12.7	106	1.98
89	1992	11	319	21.02	502	14.73	352	308	12.87	0.87	75.2	24.0	41.7	5.4	36.7	2.6	106	1.97
90	1992	12	349	18.14	433	12.72	304	235	9.83	0.77	62.9	17.2	36.0	2.2	39.5	4.1	97	1.80
91	----------																	

93	BASIC CALCULATIONS:			E	F	G	H	I	J	K	L	M	N	O	P	Q
94							delta(D)		gamma(g)							
95				Tavg	eo	ed		Lamda(L)		f(Tavg)		Rns		Rbo	Rb	Rn
96	Year	Mo	CD	C	kPa	kPa	kPa/C	MJ/kg	kPa/C	D/(D+g)	Albedo	MJ*	a1	MJ*	MJ*	MJ*
97																
98	1987	1	15	11.2	1.568	0.621	0.088	2.47	0.067	0.568	0.344	8.14	0.260	4.86	4.57	3.57
99	1987	2	46	14.1	1.852	0.734	0.105	2.47	0.067	0.609	0.324	10.70	0.262	4.79	4.53	6.17
100	1987	3	74	15.7	2.083	0.778	0.114	2.46	0.067	0.629	0.297	14.96	0.268	5.00	4.99	9.97
101	1987	4	105	22.1	3.182	0.895	0.162	2.45	0.068	0.705	0.266	19.28	0.289	5.93	6.08	13.19
102	1987	5	135	24.5	3.535	0.937	0.184	2.44	0.068	0.730	0.242	21.30	0.326	7.41	7.31	13.99
103	1987	6	166	29.9	4.935	0.843	0.242	2.43	0.068	0.780	0.230	22.98	0.357	9.56	9.71	13.28
104	1987	7	196	30.9	5.082	1.290	0.254	2.43	0.068	0.788	0.235	22.45	0.352	8.17	8.38	14.06
105	1987	8	227	32.0	5.227	1.849	0.268	2.43	0.068	0.797	0.255	18.82	0.315	5.39	5.18	13.64
106	1987	9	258	27.6	4.306	1.239	0.216	2.44	0.068	0.760	0.285	15.47	0.281	5.11	4.91	10.56
107	1987	10	288	25.2	3.632	1.716	0.190	2.44	0.068	0.737	0.315	10.34	0.265	3.25	2.70	7.64
108	1987	11	319	16.1	2.101	1.135	0.117	2.46	0.067	0.635	0.339	8.65	0.261	3.89	3.62	5.03
109	1987	12	349	10.2	1.408	0.773	0.083	2.48	0.067	0.554	0.350	6.61	0.260	4.38	3.63	2.97
110	1988	1	15	11.3	1.572	0.749	0.089	2.47	0.067	0.570	0.344	8.05	0.260	4.52	4.20	3.85
111	1988	2	46	14.7	1.989	0.883	0.108	2.47	0.067	0.616	0.324	11.14	0.262	4.44	4.38	6.75
112	1988	3	74	17.1	2.362	0.797	0.124	2.46	0.067	0.647	0.297	13.57	0.268	5.05	4.55	9.02
113	1988	4	105	19.1	2.612	1.107	0.138	2.46	0.068	0.672	0.266	16.73	0.289	5.15	4.54	12.19
114	1988	5	135	23.2	3.381	0.930	0.172	2.45	0.068	0.717	0.242	18.20	0.326	7.31	6.09	12.11
115	1988	6	166	27.8	4.394	1.218	0.218	2.44	0.068	0.762	0.230	22.59	0.357	8.26	8.23	14.36
116	1988	7	196	32.3	5.406	2.052	0.273	2.42	0.068	0.800	0.235	21.15	0.352	6.55	6.31	14.85
117	1988	8	227	31.8	5.210	1.957	0.266	2.43	0.068	0.795	0.255	19.48	0.315	5.15	5.13	14.34
118	1988	9	258	29.1	4.626	1.321	0.233	2.43	0.068	0.773	0.285	12.90	0.281	5.00	3.95	8.95
119	1988	10	288	25.9	3.824	1.515	0.198	2.44	0.068	0.744	0.315	12.07	0.265	3.72	3.65	8.42
120	1988	11	319	16.3	2.161	0.855	0.118	2.46	0.067	0.637	0.339	8.58	0.261	4.59	4.23	4.35
121	1988	12	349	11.5	1.610	0.605	0.090	2.47	0.067	0.572	0.350	7.92	0.260	4.92	4.97	2.96
122	1989	1	15	11.1	1.555	0.629	0.088	2.47	0.067	0.566	0.344	7.82	0.260	4.83	4.35	3.47
123	1989	2	46	13.9	1.891	0.846	0.103	2.47	0.067	0.606	0.324	11.17	0.262	4.49	4.45	6.73
124	1989	3	74	20.0	2.844	1.126	0.145	2.45	0.068	0.681	0.297	12.64	0.268	4.40	3.67	8.97
125	1989	4	105	22.6	3.285	1.167	0.167	2.45	0.068	0.711	0.266	19.46	0.289	5.26	5.46	14.00
126	1989	5	135	24.5	3.632	0.886	0.184	2.44	0.068	0.731	0.242	21.99	0.326	7.57	7.73	14.27
127	1989	6	166	28.8	4.758	0.899	0.229	2.43	0.068	0.771	0.230	22.97	0.357	9.27	9.40	13.57
128	1989	7	196	32.2	5.521	1.381	0.271	2.42	0.068	0.799	0.235	21.02	0.352	8.09	7.73	13.29
129	1989	8	227	30.8	5.004	1.861	0.253	2.43	0.068	0.787	0.255	19.48	0.315	5.29	5.27	14.20
130	1989	9	258	28.9	4.617	1.241	0.230	2.43	0.068	0.771	0.285	16.25	0.281	5.19	5.27	10.99
131	1989	10	288	22.8	3.240	0.997	0.168	2.45	0.068	0.713	0.315	12.06	0.265	4.80	4.70	7.36
132	1989	11	319	16.7	2.282	0.851	0.121	2.46	0.067	0.642	0.339	9.23	0.261	4.62	4.61	4.61
133	1989	12	349	11.3	1.652	0.687	0.089	2.47	0.067	0.570	0.350	7.46	0.260	4.69	4.44	3.02
134	1990	1	15	12.0	1.696	0.750	0.092	2.47	0.067	0.579	0.344	6.69	0.260	4.57	3.47	3.22
135	1990	2	46	12.5	1.747	0.736	0.095	2.47	0.067	0.587	0.324	10.25	0.262	4.69	4.23	6.02
136	1990	3	74	17.2	2.328	0.971	0.125	2.46	0.067	0.649	0.297	14.43	0.268	4.61	4.43	10.00
137	1990	4	105	20.9	2.836	1.254	0.152	2.45	0.068	0.691	0.266	15.05	0.289	4.92	3.87	11.18
138	1990	5	135	23.2	3.327	0.904	0.172	2.45	0.068	0.717	0.242	20.95	0.326	7.38	7.15	13.80
139	1990	6	166	28.8	4.661	1.180	0.229	2.43	0.068	0.771	0.230	21.66	0.357	8.47	8.07	13.59
140	1990	7	196	32.1	5.287	1.853	0.270	2.43	0.068	0.798	0.235	18.54	0.352	6.95	5.81	12.73
141	1990	8	227	30.4	4.739	1.981	0.248	2.43	0.068	0.784	0.255	13.24	0.315	5.00	3.28	9.96
142	1990	9	258	29.0	4.438	1.934	0.231	2.43	0.068	0.772	0.285	16.11	0.281	3.60	3.62	12.49
143	1990	10	288	22.9	3.245	1.214	0.169	2.45	0.068	0.714	0.315	12.60	0.265	4.26	4.37	8.23
144	1990	11	319	16.1	2.089	0.742	0.117	2.46	0.067	0.634	0.339	6.80	0.261	4.87	3.49	3.31
145	1990	12	349	10.2	1.447	0.523	0.083	2.48	0.067	0.554	0.350	7.13	0.260	5.07	4.57	2.56
146	1991	1	15	11.7	1.547	0.696	0.091	2.47	0.067	0.575	0.344	5.75	0.260	4.68	3.01	2.74

147	1991	2	46	15.9	2.128	1.064	0.116	2.46	0.067	0.632	0.324	10.08	0.262	4.08	3.61	6.47
148	1991	3	74	14.2	1.804	0.947	0.105	2.47	0.067	0.609	0.297	13.24	0.268	4.46	3.91	9.33
149	1991	4	105	18.7	2.514	1.093	0.135	2.46	0.068	0.666	0.266	18.41	0.289	5.15	5.03	13.38
150	1991	5	135	21.8	3.042	1.260	0.159	2.45	0.068	0.702	0.242	22.18	0.326	6.34	6.54	15.64
151	1991	6	166	26.2	3.881	1.500	0.201	2.44	0.068	0.747	0.230	18.49	0.357	7.41	5.95	12.54
152	1991	7	196	30.0	4.748	1.957	0.243	2.43	0.068	0.781	0.235	20.97	0.352	6.55	6.24	14.72
153	1991	8	227	31.5	5.111	1.917	0.263	2.43	0.068	0.793	0.255	19.06	0.315	5.21	5.08	13.98
154	1991	9	258	29.5	4.512	2.022	0.237	2.43	0.068	0.776	0.285	14.81	0.281	3.45	3.17	11.65
155	1991	10	288	24.9	3.581	1.420	0.188	2.44	0.068	0.735	0.315	11.47	0.265	3.88	3.60	7.86
156	1991	11	319	16.6	2.146	0.606	0.120	2.46	0.067	0.640	0.339	7.04	0.261	5.30	3.95	3.09
157	1991	12	349	12.2	1.556	0.894	0.094	2.47	0.067	0.583	0.350	6.05	0.260	4.20	3.17	2.89
158	1992	1	15	11.7	1.575	0.770	0.091	2.47	0.067	0.575	0.344	7.46	0.260	4.49	3.84	3.62
159	1992	2	46	15.5	1.958	1.099	0.113	2.46	0.067	0.626	0.324	9.60	0.262	3.96	3.33	6.27
160	1992	3	74	16.1	2.031	1.280	0.117	2.46	0.067	0.634	0.297	12.53	0.268	3.82	3.15	9.38
161	1992	4	105	21.9	3.046	1.358	0.160	2.45	0.068	0.703	0.266	15.16	0.289	4.76	3.77	11.39
162	1992	5	135	25.2	3.618	1.648	0.191	2.44	0.068	0.738	0.242	20.18	0.326	5.76	5.36	14.81
163	1992	6	166	27.7	4.279	1.680	0.217	2.44	0.068	0.761	0.230	20.20	0.357	7.16	6.33	13.87
164	1992	7	196	31.6	5.090	2.111	0.263	2.43	0.068	0.794	0.235	20.26	0.352	6.36	5.85	14.41
165	1992	8	227	33.1	5.459	2.480	0.284	2.42	0.068	0.806	0.255	18.22	0.315	4.17	3.88	14.35
166	1992	9	258	30.8	4.980	1.857	0.254	2.43	0.068	0.788	0.285	11.66	0.281	3.86	2.73	8.93
167	1992	10	288	24.6	3.460	1.466	0.185	2.44	0.068	0.731	0.315	11.15	0.265	3.76	3.38	7.76
168	1992	11	319	14.7	1.941	0.736	0.108	2.47	0.067	0.616	0.339	8.51	0.261	4.80	4.38	4.12
169	1992	12	349	9.7	1.337	0.822	0.081	2.48	0.067	0.547	0.350	6.39	0.260	4.23	3.38	3.01
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172 REFERENCE ET ESTIMATES:

173 Penman (1963), (eo-ed) = f(Tavg) — Penman-Monteith (Smith, 1991):

Row	Year	Mo	CD	Days/mo	F: f(Tavg) eo kPa	G: Rad term MJ*	H: Aero term MJ*	I: ETo MJ*	J: ETo mm/d	K: ETo In/mo	L: g* kPa/C	M: D/(D+g*)	N: Rad term MJ*	O: g/(D+g*)	P: Aero term MJ*	Q: ETo MJ*	R: ETo mm/d	S: ETo In/mo
179	1987	1	15	31	1.329	2.03	4.09	6.12	2.47	3.02	0.112	0.440	1.57	0.3347	4.95	6.52	2.64	3.22
180	1987	2	46	28	1.613	3.76	5.25	9.01	3.65	4.03	0.125	0.456	2.81	0.2931	6.44	9.25	3.75	4.13
181	1987	3	74	31	1.784	6.27	5.88	12.15	4.93	6.02	0.128	0.471	4.69	0.2777	7.46	12.16	4.93	6.02
182	1987	4	105	30	2.666	9.31	7.51	16.82	6.87	8.11	0.120	0.574	7.58	0.2398	9.40	16.98	6.93	8.19
183	1987	5	135	31	3.075	10.21	9.40	19.62	8.03	9.80	0.133	0.580	8.12	0.2144	11.68	19.80	8.10	9.89
184	1987	6	166	30	4.211	10.35	11.25	21.61	8.89	10.50	0.126	0.657	8.72	0.1855	13.79	22.51	9.26	10.94
185	1987	7	196	31	4.461	11.08	10.35	21.43	8.83	10.77	0.128	0.665	9.36	0.1789	12.59	21.95	9.04	11.03
186	1987	8	227	31	4.745	10.87	9.60	20.47	8.44	10.30	0.134	0.667	9.09	0.1700	11.69	20.79	8.57	10.46
187	1987	9	258	30	3.690	8.02	8.47	16.49	6.77	7.99	0.121	0.641	6.77	0.2026	10.36	17.13	7.03	8.31
188	1987	10	288	31	3.201	5.63	4.99	10.62	4.35	5.31	0.110	0.634	4.84	0.2263	5.84	10.68	4.38	5.34
189	1987	11	319	30	1.834	3.19	2.99	6.18	2.51	2.96	0.102	0.534	2.69	0.3076	3.47	6.15	2.50	2.95
190	1987	12	349	31	1.242	1.65	2.73	4.37	1.77	2.15	0.110	0.431	1.28	0.3472	3.29	4.57	1.84	2.25
191	1988	1	15	31	1.341	2.19	3.37	5.57	2.25	2.75	0.111	0.444	1.71	0.3347	4.23	5.94	2.40	2.93
192	1988	2	46	28	1.671	4.16	4.05	8.21	3.33	3.67	0.113	0.489	3.30	0.3050	5.21	8.51	3.45	3.80
193	1988	3	74	31	1.951	5.84	5.89	11.73	4.77	5.82	0.120	0.507	4.58	0.2770	7.63	12.21	4.96	6.06
194	1988	4	105	30	2.217	8.18	5.29	13.48	5.49	6.48	0.121	0.534	6.51	0.2611	6.91	13.42	5.46	6.45
195	1988	5	135	31	2.850	8.69	9.97	18.65	7.62	9.31	0.146	0.540	6.55	0.2130	13.30	19.85	8.11	9.90
196	1988	6	166	30	3.743	10.94	9.12	20.06	8.24	9.73	0.126	0.634	9.10	0.1980	11.52	20.62	8.47	10.00
197	1988	7	196	31	4.851	11.87	8.95	20.83	8.59	10.48	0.132	0.675	10.01	0.1688	11.12	21.13	8.72	10.64
198	1988	8	227	31	4.691	11.40	8.07	19.47	8.03	9.80	0.121	0.686	9.84	0.1768	9.45	19.29	7.95	9.71
199	1988	9	258	30	4.026	6.92	8.62	15.54	6.39	7.55	0.119	0.662	5.92	0.1942	10.19	16.12	6.63	7.83
200	1988	10	288	31	3.340	6.27	6.06	12.33	5.05	6.17	0.111	0.640	5.39	0.2202	7.03	12.42	5.09	6.21
201	1988	11	319	30	1.859	2.77	5.01	7.78	3.16	3.73	0.115	0.507	2.20	0.2884	6.08	8.28	3.36	3.97
202	1988	12	349	31	1.354	1.69	4.34	6.03	2.44	2.97	0.113	0.442	1.31	0.3304	5.31	6.62	2.67	3.26
203	1989	1	15	31	1.319	1.97	3.87	5.84	2.36	2.88	0.109	0.445	1.54	0.3403	4.62	6.17	2.49	3.04
204	1989	2	46	28	1.594	4.08	4.21	8.29	3.36	3.70	0.119	0.466	3.14	0.3028	5.54	8.67	3.51	3.87
205	1989	3	74	31	2.336	6.11	5.27	11.38	4.64	5.66	0.115	0.557	4.99	0.2603	7.02	12.01	4.90	5.97
206	1989	4	105	30	2.751	9.96	6.48	16.44	6.72	7.93	0.119	0.584	8.18	0.2375	8.33	16.51	6.75	7.97
207	1989	5	135	31	3.082	10.42	9.92	20.35	8.33	10.16	0.136	0.575	8.20	0.2120	12.80	21.01	8.60	10.49
208	1989	6	166	30	3.960	10.45	11.11	21.56	8.86	10.47	0.130	0.637	8.65	0.1897	14.34	22.99	9.45	11.16
209	1989	7	196	31	4.810	10.61	10.69	21.31	8.79	10.72	0.129	0.679	9.02	0.1711	13.19	22.21	9.16	11.18
210	1989	8	227	31	4.438	11.18	8.05	19.24	7.92	9.67	0.123	0.673	9.55	0.1816	9.77	19.32	7.96	9.71
211	1989	9	258	30	3.981	8.48	9.15	17.63	7.25	8.56	0.122	0.653	7.17	0.1934	11.15	18.32	7.53	8.90
212	1989	10	288	31	2.777	5.25	7.02	12.26	5.01	6.12	0.116	0.592	4.36	0.2388	8.36	12.72	5.20	6.34
213	1989	11	319	30	1.901	2.96	4.91	7.87	3.20	3.78	0.111	0.521	2.41	0.2911	6.08	8.49	3.45	4.07
214	1989	12	349	31	1.341	1.72	3.44	5.16	2.09	2.55	0.105	0.459	1.39	0.3461	4.37	5.75	2.33	2.84
215	1990	1	15	31	1.400	1.86	3.56	5.43	2.19	2.68	0.110	0.456	1.47	0.3317	4.64	6.11	2.47	3.02
216	1990	2	46	28	1.454	3.53	4.24	7.78	3.15	3.47	0.119	0.446	2.69	0.3138	5.60	8.29	3.35	3.70
217	1990	3	74	31	1.969	6.49	5.23	11.72	4.76	5.81	0.123	0.503	5.03	0.2725	6.88	11.91	4.84	5.91
218	1990	4	105	30	2.466	7.73	5.39	13.13	5.35	6.32	0.120	0.558	6.24	0.2490	6.80	13.04	5.32	6.28
219	1990	5	135	31	2.846	9.89	9.27	19.16	7.83	9.56	0.136	0.557	7.69	0.2200	11.88	19.57	8.00	9.77
220	1990	6	166	30	3.966	10.47	9.07	19.54	8.03	9.49	0.120	0.657	8.93	0.1953	11.03	19.96	8.20	9.69
221	1990	7	196	31	4.780	10.16	9.28	19.44	8.02	9.78	0.130	0.675	8.60	0.1711	11.19	19.79	8.16	9.96
222	1990	8	227	31	4.338	7.81	7.08	14.89	6.13	7.48	0.118	0.678	6.75	0.1866	7.99	14.74	6.07	7.40
223	1990	9	258	30	4.003	9.64	6.42	16.07	6.61	7.80	0.116	0.666	8.32	0.1964	7.39	15.71	6.46	7.63
224	1990	10	288	31	2.800	5.88	5.64	11.51	4.71	5.74	0.107	0.612	5.04	0.2450	6.40	11.43	4.67	5.70
225	1990	11	319	30	1.825	2.10	5.45	7.55	3.06	3.62	0.115	0.503	1.67	0.2908	6.31	7.98	3.24	3.83

1990	12	349	31	1.246	1.42	4.29	5.71	2.30	2.81	0.112	0.427	1.09	0.3434	4.94	6.03	2.44	2.97
1991	1	15	31	1.372	1.57	3.51	5.09	2.06	2.51	0.105	0.464	1.27	0.3432	3.80	5.07	2.05	2.50
1991	2	46	28	1.808	4.08	3.54	7.62	3.09	3.41	0.110	0.513	3.31	0.2989	4.56	7.87	3.19	3.52
1991	3	74	31	1.618	5.69	4.13	9.82	3.98	4.85	0.128	0.450	4.20	0.2887	5.13	9.33	3.78	4.61
1991	4	105	30	2.154	8.91	5.47	14.38	5.85	6.91	0.127	0.516	6.90	0.2585	7.21	14.11	5.74	6.78
1991	5	135	31	2.613	10.98	6.36	17.34	7.08	8.64	0.129	0.553	8.64	0.2347	8.40	17.04	6.96	8.49
1991	6	166	30	3.410	9.37	7.20	16.57	6.80	8.03	0.124	0.619	7.76	0.2091	8.92	16.68	6.84	8.08
1991	7	196	31	4.244	11.50	7.14	18.63	7.67	9.36	0.120	0.670	9.86	0.1878	8.50	18.36	7.56	9.22
1991	8	227	31	4.634	11.09	7.99	19.09	7.87	9.60	0.120	0.686	9.59	0.1785	9.19	18.78	7.74	9.45
1991	9	258	30	4.118	9.04	6.42	15.46	6.36	7.51	0.116	0.671	7.81	0.1930	7.28	15.09	6.21	7.33
1991	10	288	31	3.159	5.78	6.54	12.31	5.04	6.15	0.119	0.613	4.82	0.2211	7.85	12.67	5.19	6.33
1991	11	319	30	1.886	1.98	6.54	8.52	3.46	4.09	0.118	0.504	1.56	0.2830	7.46	9.01	3.66	4.32
1991	12	349	31	1.425	1.68	2.66	4.34	1.76	2.14	0.103	0.476	1.37	0.3405	2.81	4.18	1.69	2.07
1992	1	15	31	1.376	2.08	3.16	5.25	2.12	2.59	0.105	0.463	1.68	0.3419	3.63	5.31	2.15	2.62
1992	2	46	28	1.759	3.93	3.26	7.19	2.92	3.21	0.112	0.503	3.15	0.2999	3.86	7.01	2.85	3.14
1992	3	74	31	1.827	5.95	2.55	8.49	3.45	4.21	0.108	0.518	4.86	0.2993	3.11	7.97	3.24	3.95
1992	4	105	30	2.623	8.00	4.64	12.64	5.16	6.09	0.106	0.601	6.84	0.2542	5.43	12.27	5.01	5.92
1992	5	135	31	3.213	10.93	5.53	16.46	6.74	8.23	0.114	0.625	9.27	0.2225	6.54	15.80	6.47	7.90
1992	6	166	30	3.726	10.56	7.13	17.68	7.26	8.58	0.122	0.640	8.88	0.2007	8.93	17.80	7.31	8.63
1992	7	196	31	4.639	11.44	7.87	19.31	7.96	9.71	0.126	0.676	9.75	0.1759	9.35	19.10	7.87	9.61
1992	8	227	31	5.068	11.56	7.91	19.47	8.04	9.81	0.130	0.685	9.83	0.1653	9.38	19.22	7.93	9.68
1992	9	258	30	4.449	7.03	7.35	14.39	5.92	7.00	0.114	0.689	6.15	0.1857	8.33	14.48	5.96	7.04
1992	10	288	31	3.089	5.68	5.78	11.46	4.69	5.72	0.113	0.621	4.82	0.2284	6.59	11.41	4.67	5.70
1992	11	319	30	1.674	2.54	4.75	7.29	2.96	3.49	0.112	0.492	2.03	0.3065	5.55	7.58	3.07	3.63
1992	12	349	31	1.202	1.65	2.18	3.83	1.54	1.88	0.107	0.429	1.29	0.3560	2.58	3.88	1.56	1.91

SUMMARY OF REF ET ESTIMATES:

Year	Styles CIMIS		Penman: Rad term Inches	Aero term Inches	In/d	ETo Inches	Pct	Penman-Monteith (Smith, 1991): Rad term Inches	Aero term Inches	In/d	ETo Inches	Pct
1987	82.8	112.6%	39.7	39.8	0.185	81.0	105.6%	32.6	48.7	0.189	82.7	106.2%
1988	77.7	105.6%	39.0	38.0	0.179	78.4	102.3%	32.0	47.2	0.184	80.8	103.7%
1989	75.1	102.1%	40.1	40.6	0.188	82.2	107.2%	33.1	50.9	0.195	85.6	109.8%
1990	72.1	98.0%	37.1	36.1	0.170	74.6	97.3%	30.6	43.9	0.173	75.8	97.4%
1991	67.8	92.2%	39.4	32.5	0.167	73.2	95.5%	32.3	39.1	0.166	72.7	93.4%
1992	65.8	89.5%	39.2	29.9	0.161	70.5	92.0%	33.0	35.3	0.159	69.7	89.5%
Average	73.6	100.0%	39.1	36.1		76.7	100.0%	32.3	44.2		77.9	100.0%
			52.0%	48.0%				42.2%	57.8%			

Month	Penman: In/mo	Penman-Monteith: In/mo
Jan	2.74	2.89
Feb	3.58	3.69
Mar	5.40	5.42
Apr	6.98	6.93
May	9.28	9.41
Jun	9.46	9.75
Jul	10.14	10.27
Aug	9.44	9.40
Sep	7.74	7.84
Oct	5.87	5.94
Nov	3.61	3.80
Dec	2.42	2.55